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November 2002

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Behind the scenes with a planet hunter

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Founded in 1972 as a one-person kitchen table mail-order operation, Meade Instruments has grown to become a $100 million enterprise with 500 employees and with distributors in 36 countries. This record of growth has been made possible by the astronomical community — amateur and professional astronomers and educators — who have made Meade the largest-selling telescopes in the world. Now, in celebration of our 30th year, Meade LX90 and LX200GPS telescopes are available for a limited time at their lowest prices ever.

8" LX90	reg. $1695;	*now* **$1495;**	*save* **$200**
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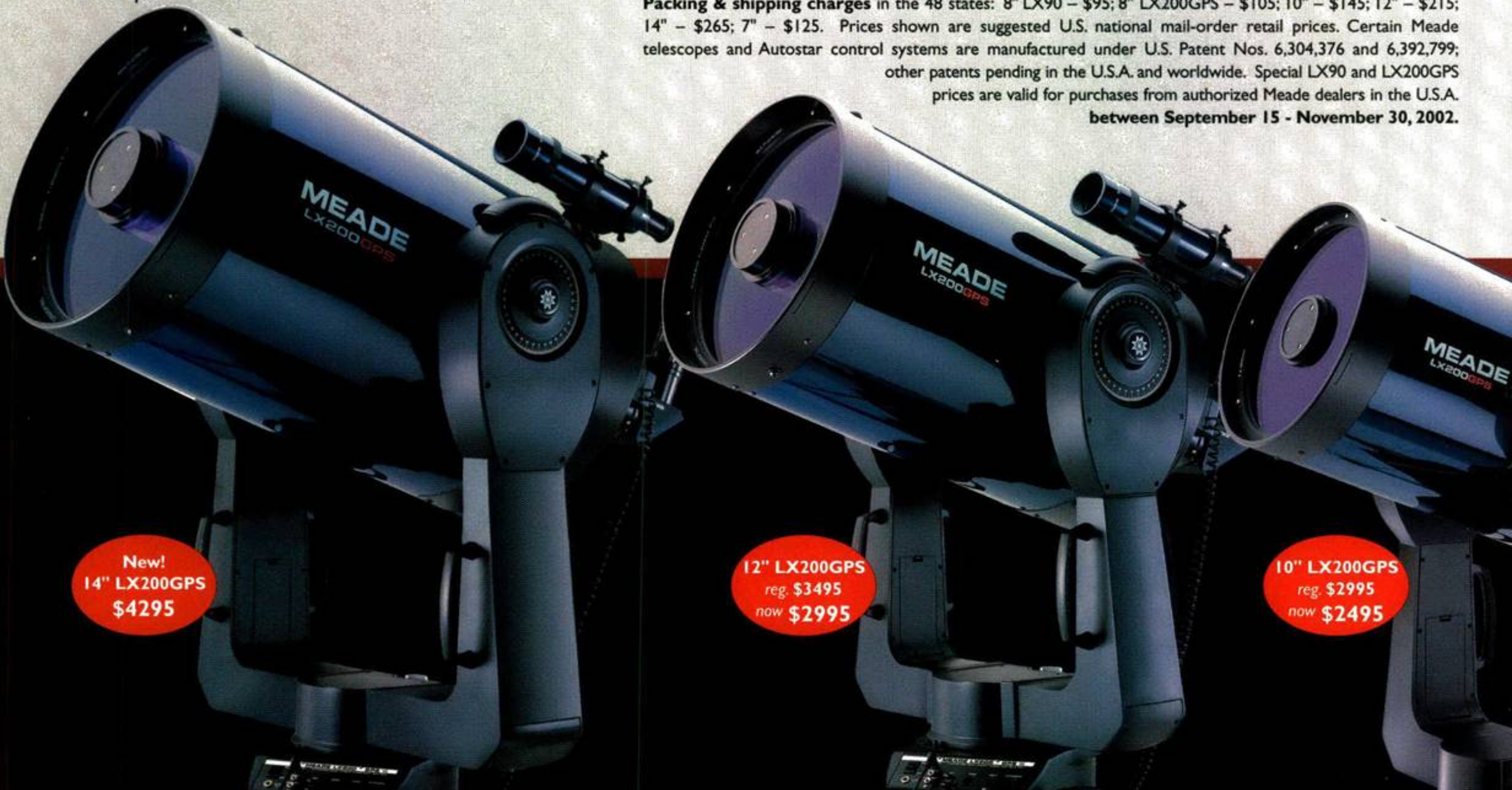
10" LX200GPS	reg. $2995;	*now* **$2495;**	*save* **$500**
12" LX200GPS	reg. $3495;	*now* **$2995;**	*save* **$500**
7" LX200GPS	reg. $2995;	*now* **$2495;**	*save* **$500**

Ultra-High Transmission Coatings (UHTC) group: *(see facing page)* 8" LX90 or 8" LX200GPS – $175; 10" LX200GPS – $235; 12" LX200GPS – $295; 14" LX200GPS – $350; 7" LX200GPS Maksutov-Cassegrain – $150.

Packing & shipping charges in the 48 states: 8" LX90 – $95; 8" LX200GPS – $105; 10" – $145; 12" – $215; 14" – $265; 7" – $125. Prices shown are suggested U.S. national mail-order retail prices. Certain Meade telescopes and Autostar control systems are manufactured under U.S. Patent Nos. 6,304,376 and 6,392,799; other patents pending in the U.S.A. and worldwide. Special LX90 and LX200GPS prices are valid for purchases from authorized Meade dealers in the U.S.A. **between September 15 - November 30, 2002.**



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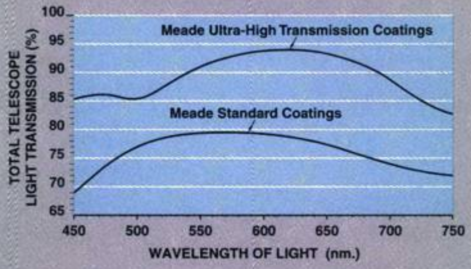
Buy a $650 Super Plössl eyepiece set for your LX90 or LX200GPS for only $99!

Through November 30, 2002, you can buy a full set of Meade premium-grade Series 4000 Super Plössl eyepieces, packed in a Meade #771 aluminum carrying case, for only **$99** with the purchase of a Meade LX90 or LX200GPS telescope.

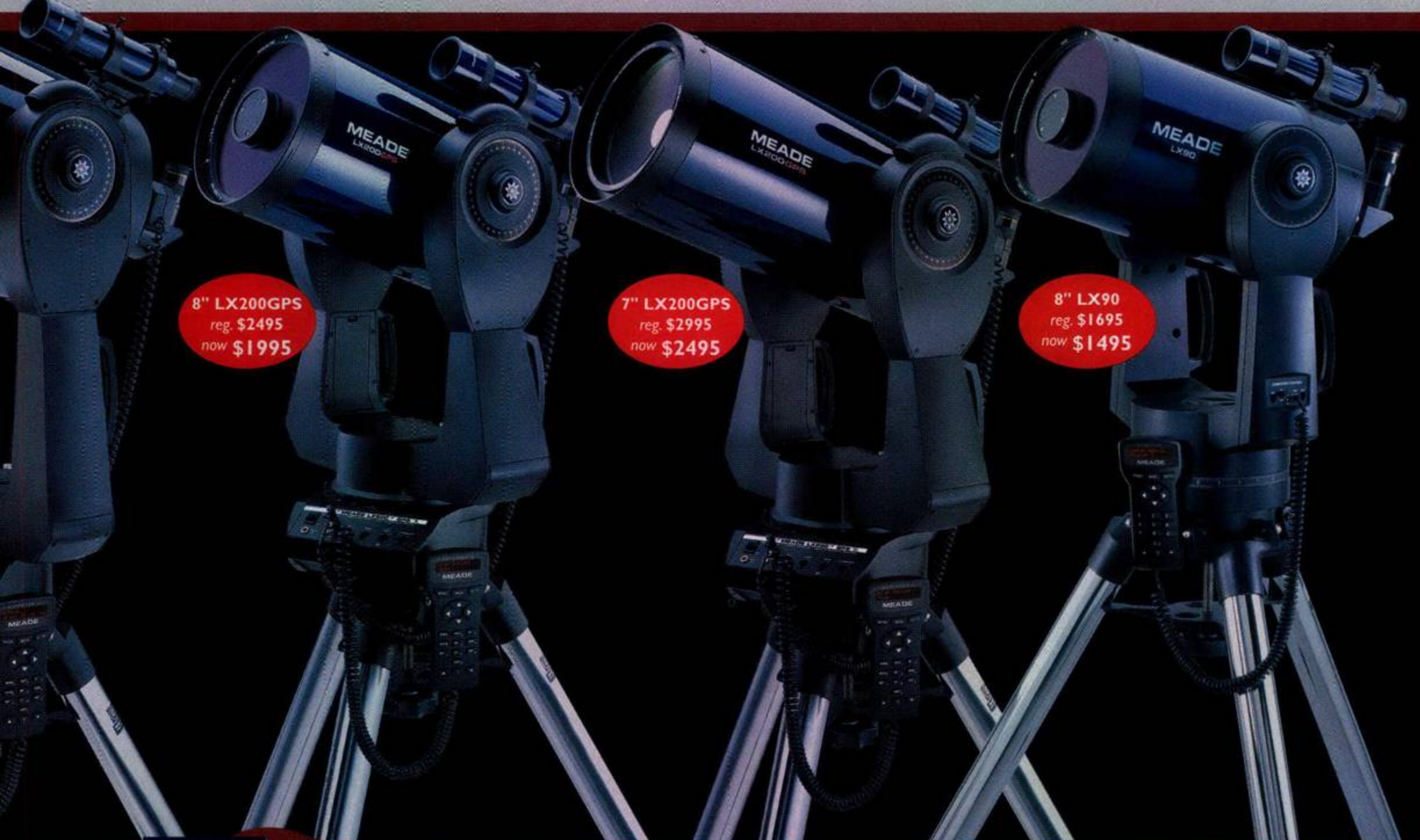
See the full-page Meade ad in this issue for complete terms and conditions on this amazing offer.

Meade Ultra-High Transmission Coatings (UHTC) Group: The optical coatings provided as standard equipment with Meade Schmidt-Cassegrains equal or exceed the reflectivity/transmission of virtually any coatings currently offered in the commercial telescope industry. Alternatively, however, the UHTC group is available optionally at the time of telescope purchase on Meade LX90 and LX200GPS models and includes an exotic series of multi-layer coatings on the telescope mirrors and on the correcting lens. The UHTC group dramatically increases image brightness by about 20% across the visible spectrum. *Image brightness of the Meade 10" LX200GPS, for example, is effectively increased by about one full inch of aperture.*



SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; operating instructions.

SPECIFICATIONS: 7", 8", 10", 12", and 14" LX200GPS — Each complete telescope includes 8", 10", 12" or 14" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); primary mirror lock; 4-speed zero image-shift microfocuser; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and 7-port multi-function control panel, including two RS-232 serial interface ports; manual and electric slow-motion controls on both axes; Autostar II control system with 3.5-Megabyte flash memory, digital readout display, permanently programmable Smart Drive and 185-speed drive controls on both axes, High-Precision Pointing, and GO TO controller; 145,000-object onboard celestial software library; GPS alignment system with 16-channel GPS receiver, magnetic declination compensation, and true-level and North electronic sensors; 12vDC telescope power supplied from internal battery compartments accepting 8 (user-supplied) C-cells (optional 25 ft. cords available for powering from auto cigarette lighter plug or from 115vAC); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12", 14"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12", 14"); operating instructions.



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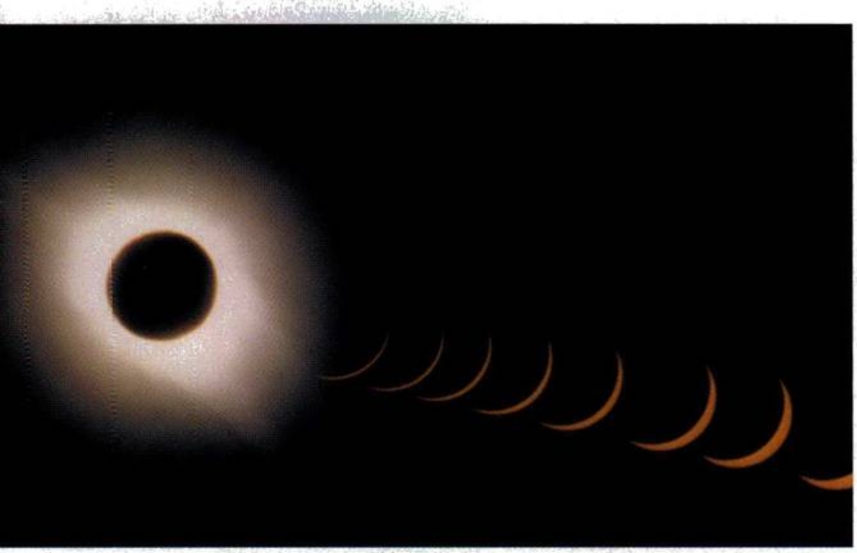

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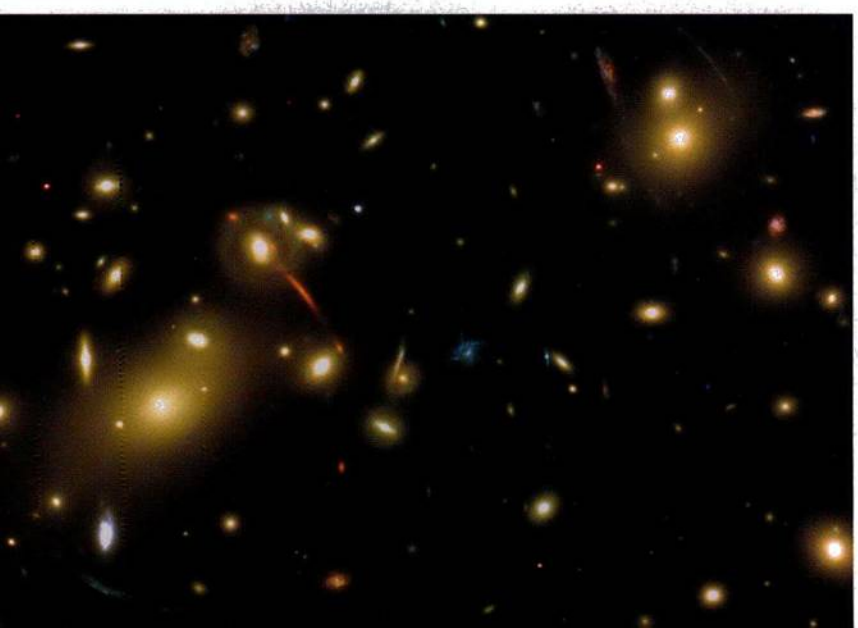

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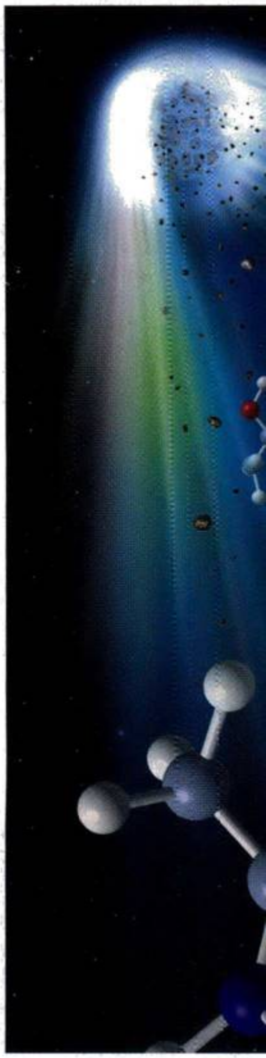

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BEHIND THE SCENES
BY DAVID J. EICHER

Meteor Madness

A storm looms on the horizon. On the night of November 18/19, earthbound observers will see what promises to be the best meteor storm to come for a generation. The Leonid shower always produces a satisfying show, with many fast and bright meteors visible even in moonlight. The last few years and this year, however, are banner years. Earth's movement through dense pockets of the meteoroid stream that causes the Leonids will give us a burst of activity.

Contributing editor Robert Burnham has penned a comprehensive viewer's guide to this year's Leonid storm (page 30). Robert's piece details how to view the storm, shows you when and where to view for maximum success, and offers tips on photographing meteors so that you can relive the event until the next possible storm comes down the pike in 29 years.

For observers in the two storm centers — the first in North and Central America, the second in western Europe, northeastern Africa, northeastern South America, New England, and parts of arctic Canada — observers could see as many as several thousand meteors per hour. The moon phase will not be ideal — full, in fact — but plenty of bright meteors will still penetrate the skyglow, particularly in the hour-long burst of greatest activity.

Another major solar system event is bearing down on us. On December 4 a total solar eclipse will wash over southern Africa, the Indian Ocean, and southeastern Australia. Many of you will undoubtedly travel to the eclipse on an expedition; ours will be led by Senior Editor Rich Talcott, and will view the eclipse from Ceduna, on Murat Bay, South Australia. Totality there will occur shortly before sunset and will last for 33 seconds. Eclipse chaser Joel Harris details the prospects for this event, with a complete guide on how to view it (page 67). If you don't get to the eclipse, fear not. Subsequent issues of *Astronomy* will feature full coverage of the eclipse experience in words and pictures — as we will with the Leonid storm.

Want to look farther afield in your quest to discover the cosmos? On page 36 science writer Joe Alper describes the significance of organic molecules falling into Earth's atmosphere and how they may have contributed to life on our planet.

Have you ever wondered what it would be like to pack bags and go along on an observing run with an astronomer hunting extrasolar planets? Bob Naeye did just that when he accompanied UC–Berkeley astronomer Debra Fischer to Lick Observatory; his story on Debra's hunt for exoplanets appears on page 48.

Finally, consider really going deep into the cosmos by reading Ray Villard's story on the Large-aperture Synoptic Survey Telescope (LSST), a proposed 8.4-meter mammoth that will be 20 times more powerful than any telescope now extant (page 42). This will, among other things, give astronomers their best-ever measurements of dark matter in the universe.

Yours truly,

Dave Eicher
Editor

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PLÖSSL 12.4mm
PLÖSSL 15mm
SUPER PLÖSSL 20mm
SUPER PLÖSSL 26mm
SUPER PLÖSSL 32mm
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Now for a limited time, to celebrate Meade Instruments' 30 years in telescopes, you can buy a Meade telescope* and receive a full set of Meade premium-grade Super Plössl eyepieces for only $99 additional. Never before have we made such an incredible offer available for such a wide range of our most popular telescope models.

Choose from more than a dozen qualifying Meade telescopes *(see listing at right)*, mail us your check for $99, and we'll ship your Super Plössl eyepiece set directly to you. And we'll pack your eyepieces in the Meade #771 foam-lined aluminum carrying case, itself a $49.95 value if purchased separately. For complete details see the HOW TO ORDER box at right.

Designed and manufactured to exacting standards, Meade Series 4000 Super Plössl eyepieces deliver wide 52° apparent fields (44° for the SP40mm) with all of the resolution, edge-of-field sharpness, and color correction demanded in the most advanced visual applications. All eyepieces are brand-new and factory fresh; each is multi-coated, includes a soft rubber eyeguard, and is individually packed in a thread-on poly container. There are no finer general-purpose eyepieces available.

The Meade #771 aluminum carrying case, included with this special offer, provides rugged, secure storage for your Super Plössl eyepiece set.

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SP6.4mm	$79.95
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SP15mm	79.95
SP20mm	79.95
SP26mm	(standard equipment)**
SP32mm	99.95
SP40mm	99.95
#771 Aluminum Carrying Case	49.95
Total price if purchased separately:	**$649.60**

***Telescopes qualifying for this special offer include:**

ETX models:	ETX-90EC, ETX-105EC, ETX-125EC
LXD55 models:	6" SN-6, 8" SN-8, 10" SN-10, 8" SC-8, 5" AR-5, 6" AR-6, 6" SN-6EC, 8" SN-8EC, 5" AR-5EC
LX90, LX200GPS models:	8" LX90; 7", 8", 10", 12", 14", 16" LX200GPS

HOW TO ORDER

1. Buy any qualifying Meade telescope from an authorized Meade dealer in the U.S.A. between August 15, 2002 and November 30, 2002.

2. Fax or mail a copy of your dealer's invoice, plus the completed warranty card packed with the telescope, along with your payment of $99 to Meade Instruments/Attn: Customer Service, and request the "$99 Eyepiece Offer." *Requests must include your complete shipping address and phone number.*

3. We will ship your eyepiece package to you within 30 days of our receipt of your request. Meade Instruments will pay for all shipping and insurance charges; safe arrival is guaranteed.

Other terms and conditions: Payment may be made by personal check (payable to Meade Instruments) or credit card (VISA or MasterCard). **California residents must add $7.67 sales tax, for a total payment of $106.67.** Requests for this special offer must be postmarked not later than December 31, 2002. This special offer is valid only for new Meade telescopes ordered and received within the U.S.A. (Outside the U.S.A. contact your Meade international distributor.) There is no limit to the quantity of telescopes each person may order: each qualifying telescope is eligible to receive the special eyepiece package. Prices shown are suggested U.S. mail-order retail prices. **The SP26mm eyepiece (shown in photos above) is packed with each qualifying telescope as standard equipment.

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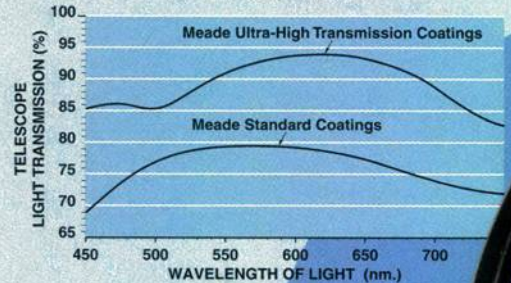
LXD55

Choose from nine Meade Schmidt-Newtonians, Schmidt-Cassegrain, and Achromatic Refractors, each with Autostar® or Electronic Controller — from $579, *complete!*

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by about 20% over the visible spectrum.



Observe ***hundreds*** of galaxies, nebulae, and star clusters of all types ***your very first night out,*** and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope fast-slews at 4.5°/second, locating each object — from the brightest to the most obscure — and placing it automatically, unerringly, and precisely in the telescopic field. Or choose one of the new EC-models with dual-axis Electronic Controller, telescopes upgradable at any time in the future to full GO TO status just by adding the Autostar hand controller.

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Meade Model SC-8
8" f/10 Schmidt-Cassegrain Telescope with standard-equipment Autostar Control System.
Complete as shown: **$1195.**

Meade Model SN-8
8" f/4 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System.
Complete as shown: **$839.**

Buy a $650 Super Plössl eyepiece set for your LXD55 telescope for only $99!
See ad in this issue for details!

6", 8", and 10" LXD55-Series Schmidt-Newtonians with Autostar

Meade American-made diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Fast f/4 (8", 10") or f/5 (6") optics present brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images reveal subtle detail often lost in telescopes of lesser resolution. The standard-equipment **Autostar Dual-Axis Control System** permits an amazing range of operations: *automatic GO TO capability* at 4.5°/second to 30,223 database objects (galaxies; diffuse and planetary nebulae; star clusters; the complete Messier, Caldwell, IC, and NGC catalogs; double and variable stars; eight major planets; asteroids; and comets); *nine selectable slew and slow-motion speeds* from 1x sidereal to 4.5°/sec.; plus *automatic sidereal-rate tracking* in RA, and much more.

SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); white-enameled metal optical tube with machined-aluminum mirror cell; quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet); operating instructions.

6" Model SN-6 Schmidt-Newtonian	**$695**
8" Model SN-8 Schmidt-Newtonian	**839**
10" Model SN-10 Schmidt-Newtonian	**995**

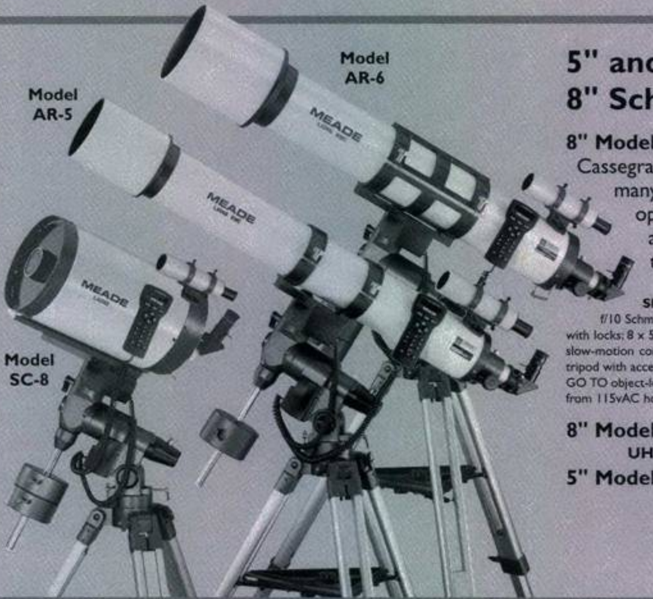
Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6 – $85; 8" Model SN-8 – $125; 10" Model SN-10 – $150.

Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95.

Model SN-6
6" Schmidt-Newtonian with Autostar

Model SN-8
8" Schmidt-Newtonian with Autostar

Model SN-10
10" Schmidt-Newtonian with Autostar



Model AR-5

Model AR-6

Model SC-8

5" and 6" LXD55-Series Achromatic Refractors and 8" Schmidt-Cassegrain with Autostar

8" Model SC-8: Includes the f/10 optical system of the Meade 8" LX200GPS for razor-sharp Schmidt-Cassegrain photo-visual imaging of the Moon, planets, and deep-space. All the telescope required by many amateurs for a lifetime of serious observing. **5" Model AR-5, 6" Model AR-6:** Excellent optical performance from the classical 2-element achromat design, with images rich in resolution and contrast and a minimum of chromatic aberration. Models SC-8, AR-5, and AR-6 allow for the full range of Autostar functions described above.

SPECIFICATIONS: Models SC-8 Schmidt-Cassegrain and AR-5 and AR-6 Achromatic Refractors — Each complete telescope includes 8" f/10 Schmidt-Cassegrain with MgF_2/standard coatings or 5" f/9 or 6" f/8 achromatic refractor with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm viewfinder; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

8" Model SC-8 Schmidt-Cassegrain . . $1195
UHTC group for Model SC-8 — $175
5" Model AR-5 Achromatic Refractor . . 695

6" Model AR-6 Achromatic Refractor . . 895

Packing & shipping charges in the 48 states: 8" – $85; 5" – $85; 6" – $95.

6" and 8" LXD55-Series Schmidt-Newtonians and 5" Achromatic Refractor with Electronic Controller

All the performance and features of the Autostar models above, but with 4-speed (2x, 8x, 32x, 4.5°/sec.) dual-axis Electronic Controller in place of Autostar. Upgrade to the Autostar Controller, available separately, at any time.

SPECIFICATIONS: Models SN-6EC, SN-8EC, and AR-5EC — Identical in every detail to the respective Models SN-6, SN-8, and AR-5, above, but with Electronic Controller (EC) in place of Autostar Hand Controller. Electronic Controller includes four dual-axis slewing speeds: 2x for photoguiding; 8x for image centering in the main telescope; 32x for image centering in the viewfinder; and 4.5°/second for rapid-slew of the telescope across the sky. ***#497 Autostar Controller may be added at any time in the future and, when plugged into the telescope's control panel, permits the full range of Autostar functions, including automatic GO TO, as described for Autostar-equipped telescopes, above.***

6" Model SN-6EC Schmidt-Newtonian	**$579**
8" Model SN-8EC Schmidt-Newtonian	**699**
5" Model AR-5EC Achromatic Refractor	**579**
#497 Autostar Controller, for any EC-model above	**149**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6EC – $85; 8" Model SN-8EC – $125.

Packing & shipping charges in the 48 states: 6" SN-6EC – $75; 8" SN-8EC – $85; 5" AR-5EC – $85. All prices shown in this ad are suggested U.S. national mail-order retail prices. © 2002

Model SN-6EC
6" Schmidt-Newtonian with Electronic Controller

Model SN-8EC
8" Schmidt-Newtonian with Electronic Controller

Model AR-5EC
5" Achromatic Refractor with Electronic Controller

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each: **$79.95** (4.54)
32mm (52°); **40mm** (44°)	each: **99.95** (5.26)
56mm (52°; 2")	**199.95** (7.02)

Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™
Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces: extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

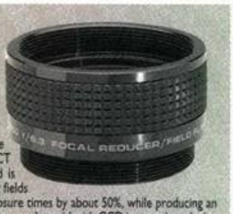
Series 3000™ Plössls
50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm (*far right in photo*), an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm $79.95** (3.86)

Series 4000™
f/6.3 Focal Reducer/ Field Flattener



Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics: multi-coated; 41mm clear aperture.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels.

$16.95 (2.73)

#911B
#911N
#908B
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

Series 4000 Oxygen-III Filters
Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade 60-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.

$49.95 (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated: 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. (Not for LX200GPS models.)

$149.95 (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to *less than one second.* A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three:

$49.95 (6.85)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$79.95 (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; 1.25": $29.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with **any** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces.
$149.95 (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces.
249.95 (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.)
15.00 (3.86)

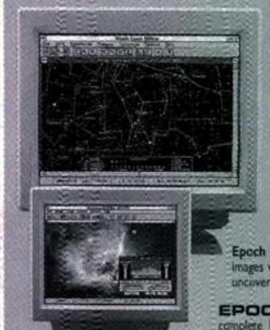
#644

#647

#1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate hand-box for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries.

$249.95 (9.85)



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $99!

Epoch 2000sk *(upper display at left)*: Use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** Dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely! Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software: Enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet.

EPOCH 2000sk Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM for Windows 95, 98, 2000, NT, and XP **$99**

LX200 Interface Cable: for Meade LX200/LX200GPS operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: On CD-ROM for Windows 95, 98, 2000, NT, and XP **99**

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated: 41mm clear aperture.

$149.95 (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

$129.95 (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

$49.95 (4.26)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

$34.95 (3.86)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics.

$49.95 (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece

A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25".

$119.95 (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25".

$219.95 (6.38)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

#774 Case for ETX-90 models:
99.95 (8.50)

#776 Case for ETX-105EC:
99.95 (8.50)

#775 for ETX-125EC:
149.95 (13.30)

Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

#670 for ETX-60/70 . . . . **19.95**
#673 for ETX-90. . . . . . . **24.95**
#675 for ETX-105. . . . . . **27.95**
#678 for ETX-125. . . . . . **29.95**

Pictor 216XT CCD Autoguider/Imager

The most advanced Autoguider/Imager in its price class. For many, all the CCD imager required for a wide range of lunar, planetary, or deep-space applications. Includes the same "point-and-shoot" simplicity of larger Pictor models. Produces smooth, natural 16-bit images of all celestial subjects. Also a precision autoguider during astrophotography.

$695. (12.00)

Advanced Field Tripod for ETX-125

#887: Yields rock-solid stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport.

$349.95 (14.00)

#889 Adapter: Available separately, permits attachment of ETX-125 to any Meade LX10 or LX200 Field Tripod or wedge. **$69.95** (7.70)

ETX® Deluxe Field Tripod

#884: Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod tilts and locks at 90° for terrestrial applications or for altazimuth use with Autostar. Telescope attaches to tripod in seconds with 2 thumbscrews. **Includes custom-fitted carry bag *(shown)* with pocket for accessories.**

$199.95 (10.00)

#771 Aluminum Carrying Case

High-quality, lightweight aluminum, suitable for storage of eyepieces, camera adapters, filters, etc. Fully foam-lined. 15" x 10" x 5".

$49.95 (5.78)

Electric Focusers for ETX®

Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models: **$119.95** (6.85)

#1247 Electric Focuser for ETX-125 models:
$119.95 (6.85)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

ANACORTES TELESCOPE, Anacortes, WA.
Orders & Information: 800-850-2001.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

WOODLAND HILLS CAMERA & TELESCOPE, Woodland Hills, CA. Orders: 888-427-8766; Info.: 818-347-2270.

EFSTONSCIENCE, Toronto, Ontario, Canada
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KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

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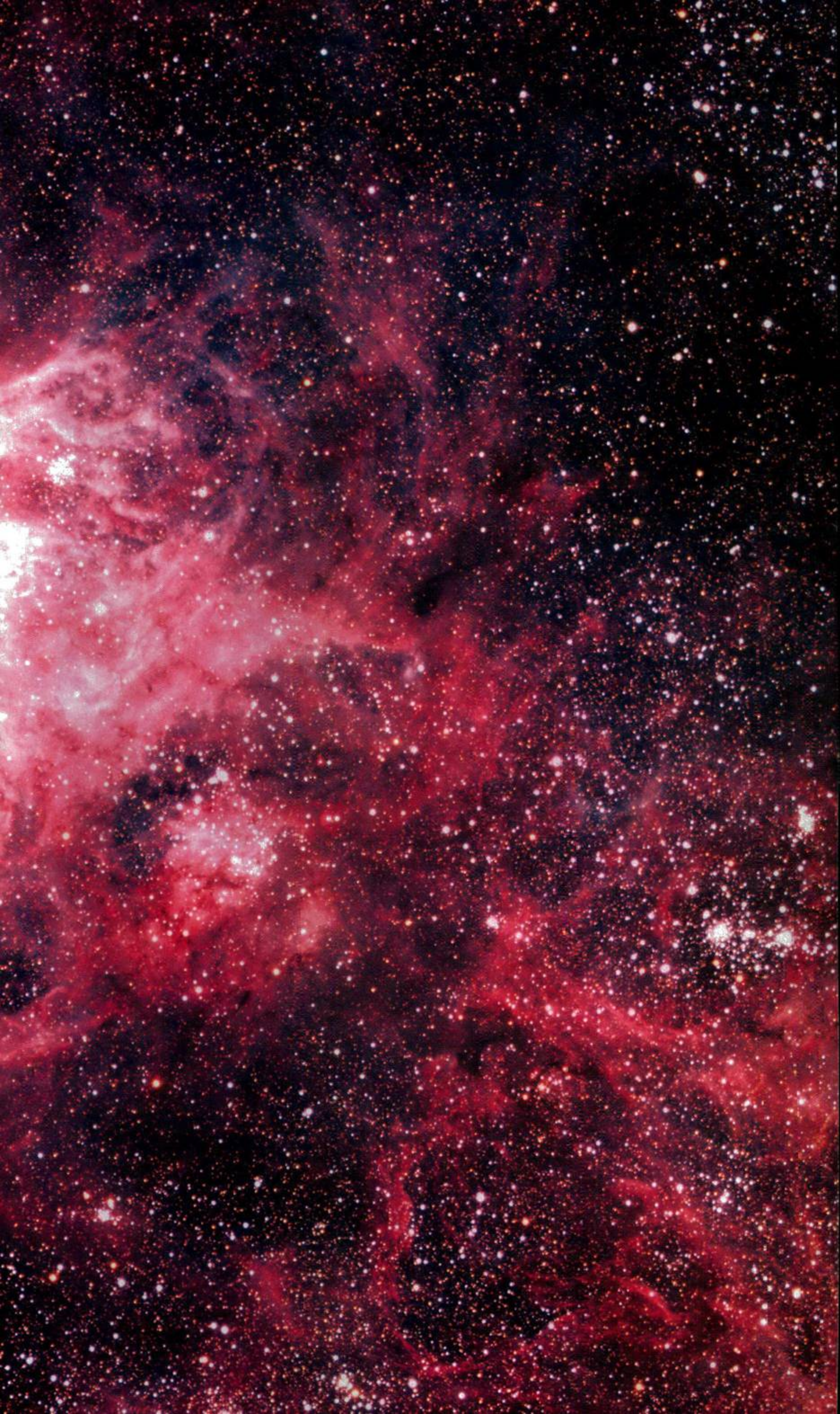


sky Gem

Trapped in a Spider's Web

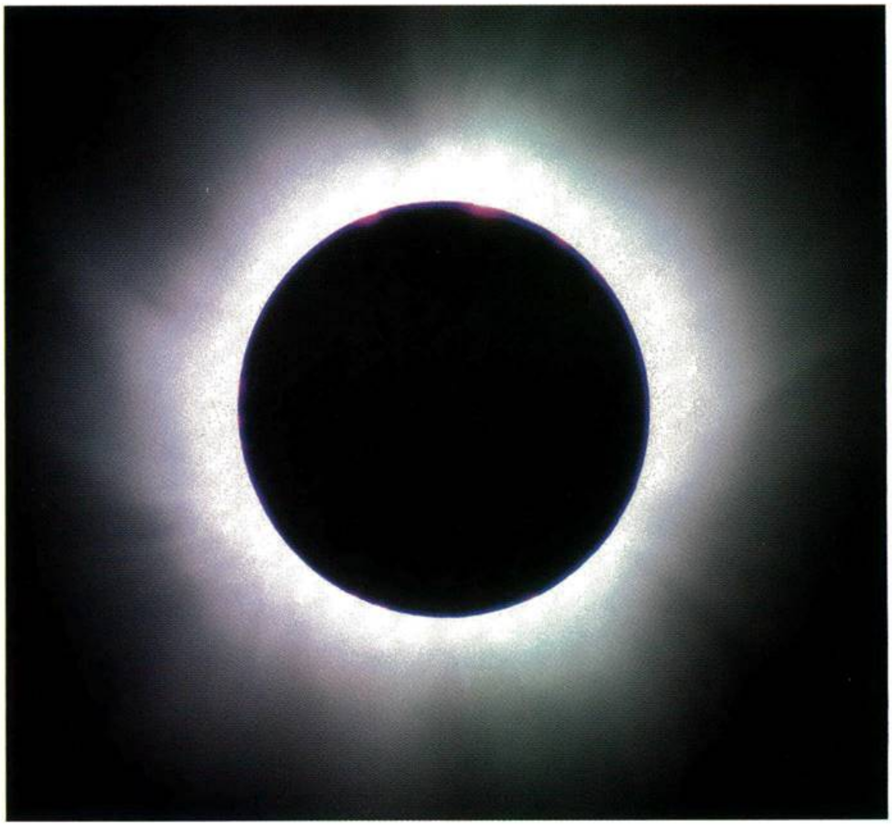
Glowing strands of hydrogen gas mark the Tarantula Nebula (NGC 2070), the grandest region of star birth in the known universe. Located 170,000 light-years away in the Milky Way's satellite galaxy, the Large Magellanic Cloud, the Tarantula spans more than 1,000 light-years and glows brightly enough to see with the naked eye.

European Southern Observatory

Eclipse Memories

I enjoyed reading Tom Murphy's memories of the 1998 solar eclipse in Venezuela ("A Once-in-a-Lifetime Chance," Hot Shots, August 2002). I was there also and share many similar memories. For me, the most striking thing about the eclipse was that for the first time in my life I had a clear view of the solar system. To see the totally eclipsed sun with Mercury, Venus and Jupiter in their orbits around it was to see the solar system in real life, as it is impossible to see at any time other than during a total eclipse. It was a sight I will never forget.

I would also like to correct an error in the article. The author refers to the eclipse as being "the last solar eclipse in the Western Hemisphere in the 20th century." It may have been the last in the Americas and the last taking place entirely in the Western Hemisphere, but it was not the last to be seen there. That honor went to the eclipse of August 11, 1999. From my location in the British Isles, it was the eclipse of the century. — *David Le Conte, Guernsey, British Isles*



Viewing the sun's corona can be an unforgettable experience. Luc Viatour

Astronomy Club Tips

Recently, our local astronomy club, the Gaston County Skywatchers in North Carolina, was having trouble finding a good observing site. All the available backyards were small, light polluted, and obscured by trees. We looked at other options, and made a list of organizations in our area that might have sites they could share, but nothing panned out. I decided to check out our local County Parks and Recreation website and began searching through the 17 parks that were listed. One of the listings, "The Lewis Brooks Airfield," looked promising. It was located on a closed county landfill and was being used by an R/C (radio-controlled aircraft) flying club. That meant it likely had lots of open space and no use during the evening hours.

I sent a letter to the director of the County Parks Commission asking if the site might be available for our use. Her response was positive, and after I sent a second letter describing our club's activities, our request was approved.

After meeting with the president of the R/C flying club, I learned that many similar clubs around the country are located on closed landfill sites. If your astronomy club needs an observing home, this may be a solution. — *Otto L. Danby II, Gastonia, North Carolina*

Gravity Boosts

In Ask Astro (September 2002), Michael J. S. Belton gave an eloquent explanation of the process of gravity-assisted planet flybys of spacecraft. However, I feel that an important point was left out, which is that it is the motion of the planet that is the real aid. If the flyby is in the same direction as the planet's orbital motion, the craft will experience positive acceleration. Conversely, if the probe is moving against the planet's motion, it will result in negative acceleration, hence "gravity braking." — *John R. Peterson, Salt Lake City, Utah*

Correction

On page 78 of the September issue, the photo by John Chumack shows the red giant Arcturus, not Betelgeuse.

Astronomy invites you to talk back. Send letters to Astronomy *Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space and clarity. Please include your city, state, and country with all correspondence. If you want to talk back to us, please visit our website, http://www.astronomy.com.*

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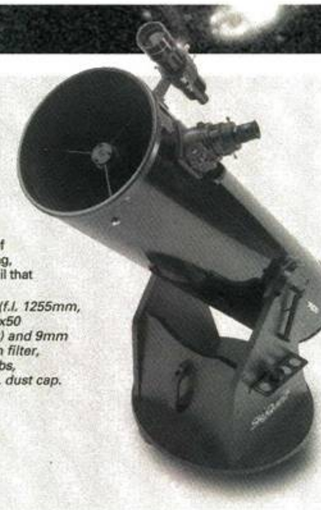

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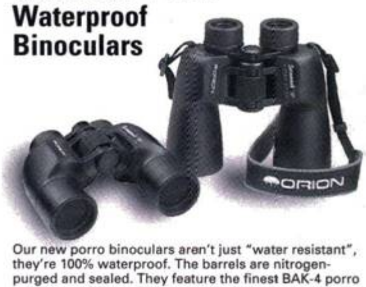

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When Black Holes Collide

▶ Astronomers often ponder seemingly poetic questions: If galaxies collide, do their hearts merge as well, or are they destined to remain forever separate?

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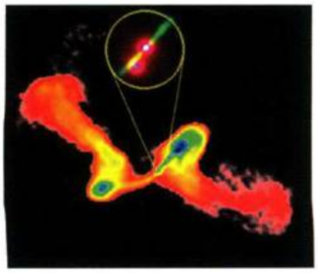
"Most astronomers assume that nature finds a way to bring the black holes together, since we don't see strong evidence of binary black holes at the centers of galaxies," says one author, Rutgers University theorist David Merritt. "We now have solid evidence that the black hole mergers actually take place."

Radio jets shooting from the core of the galaxy NGC 326 have changed direction suddenly, probably as the result of a black hole merger. The inset shows the nucleus and jets pointing in the 8 o'clock and 2 o'clock positions. Previously, they pointed toward 10 o'clock and 4 o'clock.

NRAO/AUI; STScI (inset)



Merritt and his partner, radio astronomer Ronald Ekers of the Australia Telescope National Facility, studied galaxies with odd-shaped radio emissions that had previously been observed with the Very Large Array in New Mexico. These strange galaxies have four lobes that appear to form an X in radio images.

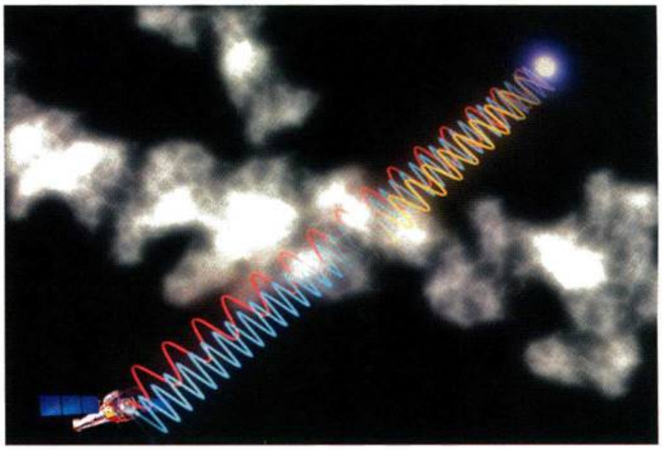
According to the two scientists, these lobes are actually jets that propel radio-emitting particles from galactic cores. The jets shoot from a disk of material circling a galaxy's central black hole and are aligned along the black hole's spin axis. Merritt and Ekers believe the X shape arises when the central black hole in each galaxy is knocked over, changing the jets' direction. While one pair of jets points out the hole's previous orientation, the other pair reveals the hole's new spin axis.

"Black holes are so large and so massive," says Merritt, "the only thing we can imagine that would have enough force to realign them is another black hole." Using a computer model, he and Ekers calculate that one black hole could realign another that's up to five times its mass.

About seven percent of radio galaxies are known to have an X shape. This and the estimate that the radio lobes of these galaxies last for 100 million years suggest black hole mergers happen somewhere in the universe once per year.

"We have known about X-shaped galaxies for a long time, but until now we have never had a convincing explanation for them," adds Merritt. "Most astronomers were fairly sure that black holes coalesce, but we now regard the X-shaped galaxies as the first 'smoking-gun' evidence."

— VANESSA THOMAS



SAO/CXC/A. Hobart

In this artist's concept, Chandra measures x rays from a distant quasar as they pass through a cloud of intergalactic gas. By measuring the amount of absorption by elements in the cloud, astronomers estimated its temperature, density, and mass.

LARGE-SCALE STRUCTURE

Chandra Spies Invisible Web

▶ During the first few billion years that followed the Big Bang, about 20 percent of the matter in the universe collapsed under the influence of gravity to create stars and galaxies. The rest, which consisted of both normal matter and dark matter, formed a filamentary network that connected clusters of galaxies throughout the universe.

That's how theorists have told the story of the early universe. Until recently, though, this filamentary web had escaped detection because its gas is much too hot to be seen by any optical, infrared, or radio telescope. Now, four independent teams of researchers have used the Chandra X-ray Observatory to discover parts of the giant, cosmic web.

"We had strong suspicions from the Big Bang theory and observations of the early universe that this gas exists in the present era, but like a stealth aircraft it had eluded our detection," says Claude Canizares of the Massachusetts Institute of Technology, who led one of the teams with MIT colleague Taotao Fang.

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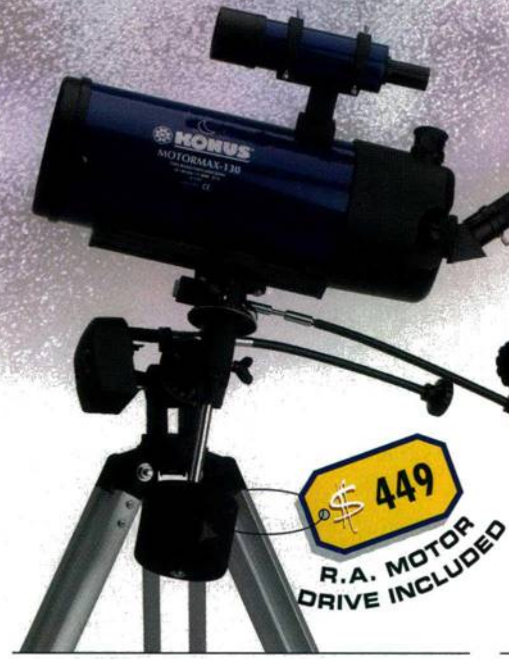

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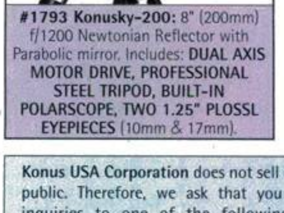

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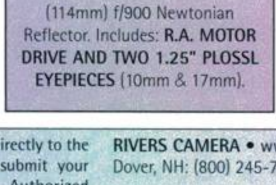

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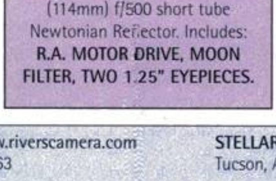

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The MIT team, along with others from Ohio State University and the Harvard-Smithsonian Center for Astrophysics, used Chandra to study x-ray emissions from distant quasars. Some of the x rays from these quasars get absorbed by the intervening filaments of gas, and Chandra noticed this x-ray dimming.

From the amount of x rays absorbed, the scientists estimated the temperature, density, and mass of the gas in the sections they found. The searing gas ranges from 300,000 to 5 million degrees Celsius (540,000 to 9 million degrees Fahrenheit). One of the filaments appears to contain our Milky Way Galaxy and the nearby Andromeda Galaxy, while others are a few billion light-years away.

Joel Bregman and Jimmy Irwin of the University of Michigan had earlier found evidence for the mysterious hot gas by studying the x rays it emitted, which subsequently were absorbed by a galaxy located between the source and Earth. "Normally a doctor studies the x-ray shadow produced by your bones to learn about your bones," says Bregman. "In essence, we used the shadow to learn about the x-ray machine." All four teams have published their findings in *The Astrophysical Journal.*

Theorists believe there is more mass in just the gaseous component of this newfound web than there is in all the stars throughout the universe. Even more mass is believed to be tied up in dark matter. The newly unveiled gas could help astronomers trace the location and nature of this dark matter. — V. T.

COMET MISSION

CONTOUR May Be Split in Two

▶ The hopes of planetary scientists were dashed in mid-August when the Comet Nucleus Tour (CONTOUR) spacecraft fell silent. Launched on July 3 to take closeup looks at two or more comets over the next few years, CONTOUR failed to radio Earth following a planned rocket firing on August 15.

At 4:49 A.M. EDT, CONTOUR was expected to fire its solid rocket motor and boost itself out of Earth orbit toward a November 2003 rendezvous with Comet Encke. At the time, it was out of reach of the Deep Space Network (DSN), the international system of antennas that support spacecraft missions.

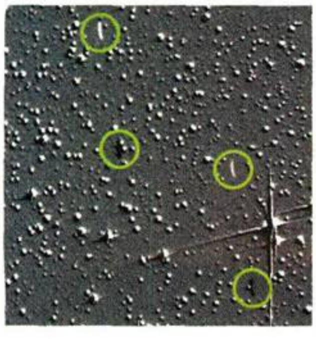
CONTOUR team members had encouraged amateur astronomers to observe the craft before and after the firing. At that time, it would have been visible only to skywatchers in Australia, New Zealand, and the western Pacific, but according to team member David Dunham, no sightings were reported.

About 45 minutes after the firing, the team expected to hear from CONTOUR, but the DSN never found a signal. Several minor problems might have caused this radio silence, so without too much worry, engineers immediately began running backup plans. The team hoped a pre-programmed maneuver the next morning to turn CONTOUR about 40° would improve the spacecraft's signal. But the time came and went with no sign, and "we got rather concerned," said mission director Robert Farquhar of Johns Hopkins University Applied Physics Laboratory.

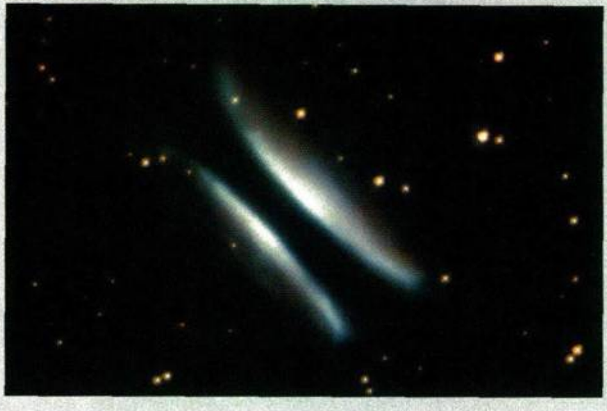
Soon after they lost contact, mission managers sent out a call to observatories around the world to help look for the spacecraft. Poor weather plagued Mauna Kea in Hawaii and LINEAR's observing location in New Mexico, but clear weather

Could these be parts of the CONTOUR spacecraft? A pair of moving objects shows up in this image taken at two separate times on August 16, 2002, with the 1.8-meter Spacewatch telescope on Kitt Peak. The white images were taken earlier.

Spacewatch Project/Lunar and Planetary Laboratory/University of Arizona



HUBBLE SPACE TELESCOPE



NASA and the Hubble Heritage Team (STScI/AURA)

WHERE'S THE BEEF? At first glance, it might seem to be hovering in the constellation Sagittarius, but this Hubble image actually shows the protoplanetary nebula IRAS 18059–3211. Better known as Gomez's Hamburger, after its discoverer, astronomer Arturo Gomez, it is the cast-off shroud of dust and gas from a dying, sunlike star. Roughly 6,500 light-years from us, the red giant causes the "buns" to light up while a thick, edge-on band of dust circling the star blocks all starlight and serves as the dark "patty" in the middle. Its unusual shape puzzles astronomers. "The easiest way to explain this would be ... if the star had a nearby companion, then tidal forces could make it continue to rotate more rapidly," says Howard Bond of the Space Telescope Science Institute, who helped obtain the image. In that case, most of the material would get ejected along the plane of the star's equator. In less than 1,000 years, Gomez's Hamburger will probably finish puffing out its outer layers to become a full-fledged planetary nebula.

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graced the sky above the 1.8-meter Spacewatch telescope in Arizona. Early on August 16, Spacewatch astronomers spotted what appeared to be CONTOUR — and then noticed a second object nearby, moving in the same direction.

Farquhar, who spoke to reporters that afternoon, said the CONTOUR team had "some optimism up until this time." But he added, "Looking at this image, I don't feel very good about it."

According to Dunham, the pair of objects were about 0.6° away from CONTOUR's expected position. Spacewatch's image of the parallel-moving objects, along with the lack of communication from CONTOUR, suggested the spacecraft may have split in two.

The objects were then 155 miles (250 kilometers) apart and about 250,000 miles (400,000 km) from Earth. That distance implies that the solid rocket fired successfully and the spacecraft had left Earth orbit.

As *Astronomy* went to press in late August, Farquhar had not yet lost all hope. He pointed out that the NEAR-Shoemaker spacecraft also went quiet for a couple of days in 1998 before it was successfully recovered and sent on its way toward asteroid Eros. And in early December, CONTOUR should come into a more favorable angle for receiving a signal from Earth. "We know there's not much room for optimism," says Farquhar, "but it's still worth monitoring." — V. T.

DWARF GALAXIES

Galaxy Breathes Out Fresh Air

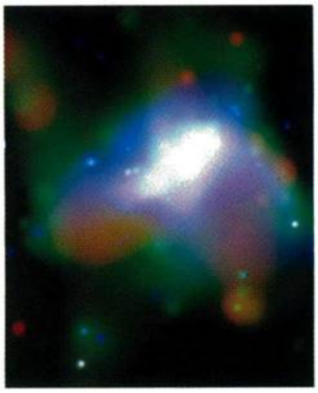
▶ Dwarf galaxies may be the runts of the universe's galactic litter, but observations by the Chandra X-ray Observatory suggest they're a force to be reckoned with. They may be largely responsible for supplying intergalactic space with the materials that formed our planet, the elements that make up our bodies, and the air we breathe.

Chandra spied the nearby dwarf galaxy NGC 1569 releasing huge amounts of oxygen and other heavy elements in bubbles thousands of light-years wide. According to a team of astronomers led by Crystal Martin of the University of California, Santa Barbara, there's probably as much oxygen pouring out of NGC 1569 as contained in 3 million suns.

Located 7 million light-years from Earth, NGC 1569 has been experiencing a burst of star formation and supernovae during the past 10 million to 20 million years. As these supernovae explode, they eject heavy elements into the galaxy at high speeds. This gas heats up as it rams into other gas in the area and then "boils" out of the galaxy's disk in bubbles.

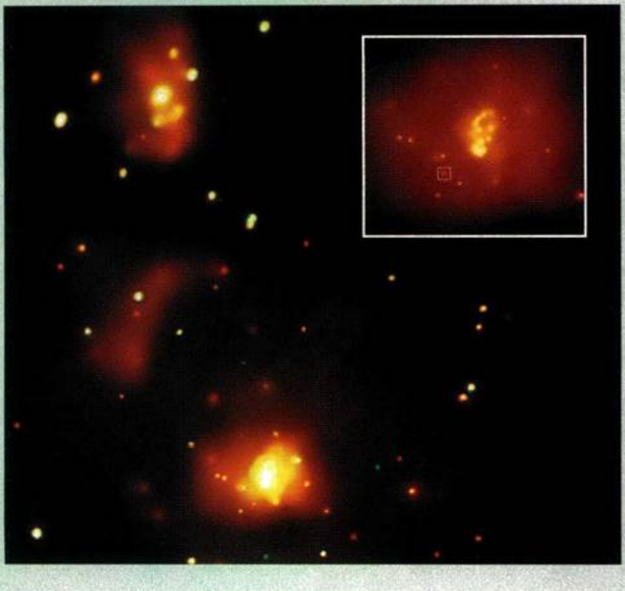
"Dwarf galaxies are much smaller than ordinary galaxies like our Milky Way," Martin explains. "Because of their small mass, they have relatively low gravity, and matter can escape more easily than from normal galaxies. This makes them very important in understanding how the universe was seeded with various elements."

Heavy elements, which collectively make up a measly 1.9 percent of the universe's mass, are necessary for planetary formation and life. And because enriched gas cools more



This x-ray image of NGC 1569 shows large hot bubbles of gas extending above and below the galaxy's disk. NASA/CXC/UCSB/C. Martin et al.

CHANDRA X-RAY OBSERVATORY



NASA/CXC/University of Maryland/A. Wilson et al.

X RAYS POUR FROM HOT GAS in the central regions of NGC 5194 (bottom) and NGC 5195 (upper left), collectively known as the Whirlpool Galaxy (M51) in Canes Venatici. The large number of point sources spread throughout the region are black holes and neutron stars feeding off their binary companions. The inset shows an expanded view of NGC 5194's core. Astronomers think that the clouds of multimillion-degree gas extending north and south of the nucleus are heated by high-velocity jets produced near a supermassive black hole at the galaxy's center. A faint source at the lower left of the inset (inside the white box) is the remnant of an unusual, Type Ic supernova first seen on Earth in 1994. This variety resembles the traditional type II supernova that results when a massive star explodes after exhausting its nuclear fuel. In a Type Ic, however, the star loses its outer layers of hydrogen and helium thousands of years before the explosion, either through a strong stellar wind or transfer to a companion.

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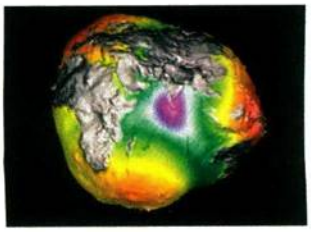
quickly, the dispersion of this matter by dwarf galaxies could have played a role in the rate that other galaxies developed.

Martin and her colleagues, Timothy Heckman of Johns Hopkins University and Henry Kobulnicky of the University of Wisconsin, used Chandra to observe NGC 1569 for 27 hours in April 2001. The concentrations of oxygen, neon, magnesium, and silicon indicate that the elements come from thousands of supernovae in the galaxy. — V. T.

EARTH'S GRAVITY FIELD

Our Roly-poly Planet

▶ It's familiar to anyone who's tried to lose weight: As soon as one area starts to trim down, another balloons up. A similar shifting of mass happens with Earth, which is slightly wider around the middle than it is tall. For the last 10,000 years or so, the planet has been slowly tightening its belt, its mass traveling toward the poles. But in the last four years, researchers have noticed an abrupt turnaround — Earth is gaining back its spare tire — and the culprit appears to be climate change.



This model exaggerates the uneven mass distribution of Earth. GFZ-Potsdam

"We're not measuring Earth's radius itself," says Benjamin Chao, a geophysicist at NASA's Goddard Space Flight Center and one of the chroniclers of this shift. "We're measuring the effects of its changing gravity field." For 25 years, researchers have tracked the movement of satellites by shooting laser beams at them from Earth. Because the pull of gravity is directly related to the amount of mass, maps of the planet's mass distribution can be made by recording changes in satellites' positions.

The data showed a steadily decreasing waistline — known as post-glacial rebound — which scientists attribute to a springiness in Earth's mantle. Ice from the last Ice Age had pressed down on the poles like a vise, causing the planet's middle to expand. When the ice melted about 10,000 years ago, Earth began to spring back, transferring its mass from the equator toward the poles.

"It's still rebounding today," says Chao. "We're still seeing the northern part of Europe and Canada rising. But in the last few years, the trend is reversing. Something else is causing Earth to become more oblate. It's a big surprise."

In a paper published in the August 2 *Science*, Chao and colleague Christopher Cox discuss the possible triggers of the reshuffling of Earth's mass. They dismissed both atmospheric events and melting polar ice (ten times more ice would have had to melt than estimates to account for the extra girth). That leaves the oceans as the most likely suspect, with changing currents the conduit for the movements of mass. And changes in the ocean mean one thing to those in the know — something is afoot with the world's climate.

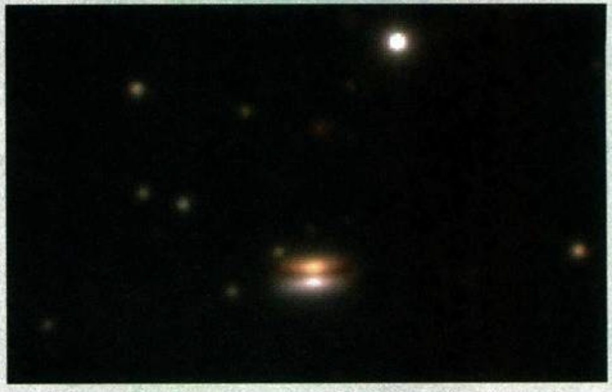
"What we're seeing is definitely climate variations," says Chao. In fact, the gravitational field changes began at the time of the strongest El Niño event of the century, write scientists in an accompanying article. Models suggest this recurring but irregular cycle of shifts in ocean and atmospheric conditions could move water to the tropics, which might account for the equatorial bulge. "Whether this is a natural, regular thing that will come back later or a one-time thing we don't know," says Chao, who doesn't rule out global warming as a cause.

But lest you worry about Earth bursting its seams, Chao reassures, "We're talking about very small effects. It's not like Earth's gravity is going to change overnight." Earth is about 1/300th wider than it is tall, but it has added only about one part in 100 million to its belly in each of the last four years.

Such small changes attest to the sensitivity of the satellite data, which is due to get even finer now with a pair of satellites launched in March called GRACE (Gravity Recovery and Climate Experiment). These will bounce radio beams between them and produce even more subtle maps of Earth's gravity field.

— MAGGIE MCKEE

VERY LARGE TELESCOPE



European Southern Observatory

A PORTRAIT OF THE SUN AS A YOUNG STAR would look something like the odd object seen below center in this image from the 8.2-meter Very Large Telescope. The object was found by accident on the outskirts of the Rho Ophiuchi dark cloud, a star-forming region some 500 light-years from Earth. Nicknamed the "Flying Saucer" by the astronomers who discovered it, the object consists of a sunlike star about 1 million years old sitting inside a dusty circumstellar disk. The disk has a radius about five times the distance of Neptune from the sun, or roughly 30 billion miles, and contains enough raw material for a planet system. Team leader Nicolas Grasso of the European Southern Observatory says: "The 'Flying Saucer' object presents us with a striking portrait of our solar system in its early infancy."

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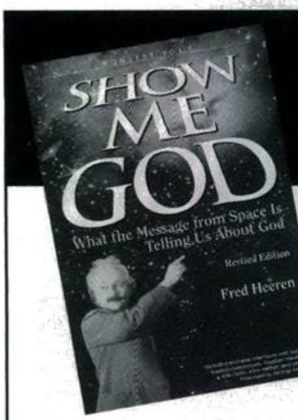

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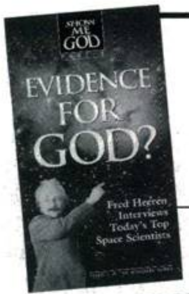

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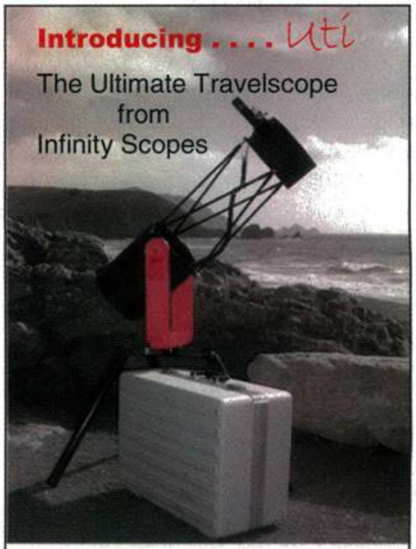

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MARTIAN METEORITES

Life-on-Mars Debate Heats Up

Soon after scientists announced in August 1996 that possible signs of ancient life exist in the martian meteorite ALH84001, others countered with alternative explanations. Most recently, the six-year debate has revolved around magnetite crystals in the meteorite that resemble those produced by aquatic bacteria on Earth. These crystals act as compasses, helping bacteria find food and energy. Yet, the debate rages because the crystals can form inorganically, too.

In the August issue of *Applied and Environmental Microbiology*, a team of nine researchers headed by Kathie Thomas-Keprta, an astrobiologist at NASA's Johnson Space Center, reports that some 25 percent of the magnetite crystals in ALH84001 have passed a set of criteria that only biological magnetite crystals have ever met before.

The test is a set of six properties the team calls the Magnetite Assay for Biogenicity (MAB). Four of the properties relate to the crystals' external structure, one to their internal structure, and the last to their chemical composition.

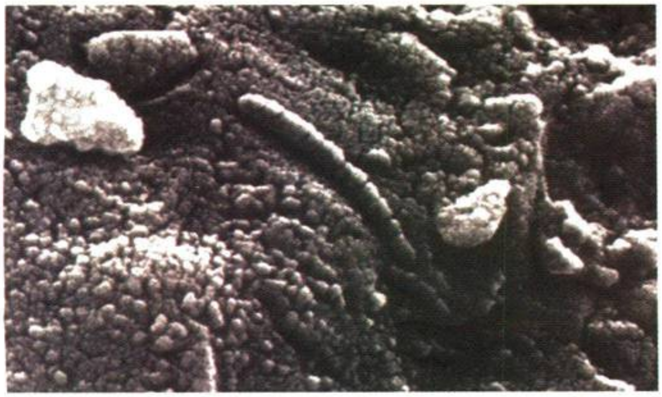
"No non-biologic magnetite population, whether produced by nature or in the laboratory, has ever met the MAB criteria," says Thomas-Keprta. "This means that one quarter of the magnetite crystals embedded in the carbonates in ALH84001 require the intervention of biology to explain their presence."

The researchers had previously noticed the magnetite crystals in the martian meteorite bear strong physical and chemical resemblances to those produced by a bacteria strain on Earth called MV-1. This is the first time, though, that they'd applied the full MAB test to the extraterrestrial crystals.

"We believe this latest study proves that the magnetites in ALH84001 can be best explained as the products of multiple biogenic and inorganic processes that operated on early Mars," says Thomas-Keprta. — V. T.

For the latest astronomy news as it breaks, visit us at www.astronomy.com

This tiny, worm-like formation was found in a carbonate globule in martian meteorite ALH84001. NASA

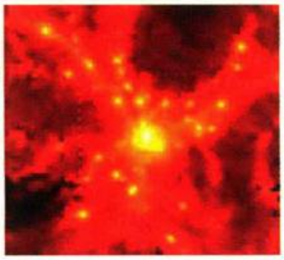


Breaking Up Is Easy to Do

First seen more than 60 years ago, Comet 57P/du Toit-Neujmin-Delporte slimmed down for its latest swing past the sun. It has shed at least 19 pieces that trail its nucleus like Hansel and Gretel's bread crumbs. Based on the fragments' magnitudes, University of Hawaii astronomer Yan Fernández estimates that each piece is tens to hundreds of meters across. "It is hard to say because the fragments are surrounded by a lot of dust," he says. "We don't really have a good idea of what the original size of the main comet's nucleus was either." The breakup looks familiar to those who remember Comet C/1999 S4 (LINEAR), which crumbled after the sun's heat burned off much of the ice that held it together.

Gamma-ray Background Source Found

New research suggests that the gravitational pull from massive galaxy clusters may be the source of most of the mysterious gamma-ray background that astronomers see coming from every direction in the sky. Theorists predicted two years ago that free electrons dragged toward the clusters would slam into microwave photons from the Big Bang, producing these gamma rays. Caleb Scharf of Columbia University and Reshmi Mukherjee of Barnard College tested the theory by comparing nine years of data compiled from NASA's Compton Gamma-Ray Observatory with a catalog of 2,469 galaxy clusters. Indeed, the most massive clusters showed the brightest gamma-ray haloes, suggesting the gamma-ray background might trace the universe's large-scale structure.



A computer simulation shows galaxy clusters aglow in gamma rays. Uri Keshet et al., in "Gamma-Rays from Intergalactic Shocks"

Dust in Earth's Attic

It's amazing what you can find in an old attic: treasure chests full of interesting heirlooms, portraits of ancestors, and, well, lots of dust. Now a team of astronomers has surmised that our planet has its own dust-filled attic — the moon. Finding rocks blown from Earth onto the moon during the period of heavy bombardment almost 4 billion years ago may help researchers understand how life on Earth originated. These "terran" meteorites might be up to six feet wide, says Jordi Guitterezz, a scientist at the Technical University of Catalonia in Barcelona, Spain. He and some colleagues now believe there might be a scientific goldmine in or under lunar soil. "Protected inside the body of these large rocks it could be possible to find microfossils," he says. While differentiating between Earth and lunar material might be a challenge, he believes it can probably be done.

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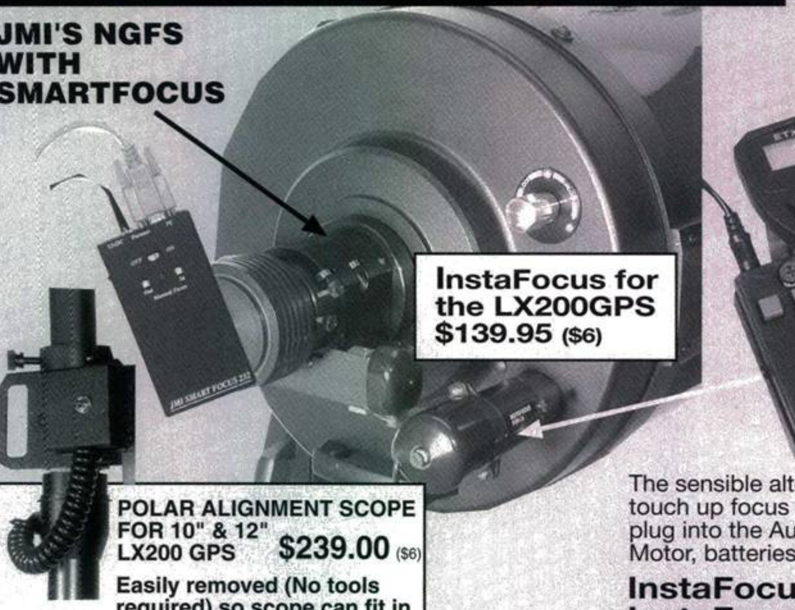

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STORM WARNING

Forget the scattered

by Robert Burnham

showers of past years – this year the Leonids should storm.

Mark your calendar: The night of November 18 is showtime for the Leonid meteors. Yes, the moon is nearly full that night, and, yes, its light will erase the fainter meteors. But the prospects for a Leonid storm are excellent — and it will be the last such squall for a generation to come.

After darkness falls that night, a few Leonid meteors will streak every hour, and despite the moon, more will appear once Leo rises in late evening. What all observers are looking for, however, is a Leonid storm — an incredibly rich shower of meteors filling the sky. Most years, the Leonid shower produces one or two meteors a minute, but Leonid storms boost meteor activity by a hundredfold or more. That's a sight every skywatcher hopes to experience at least once.

This year, one Leonid "storm center" lies over western Europe, northwest Africa, northeastern South America, New England, and parts of arctic Canada. The other encompasses all of North and Central America. (See the maps on page 33.) Of the two, the North American display will be the better.

Rivers of Dust

These meteors take their name from Leo the Lion, the constellation they appear to originate from. If you trace back the path of a few Leonids, you'll find they converge on a point (called the radiant) that lies in the center of Leo's head, not far from the bright star Regulus. The meteors are actually traveling parallel as they fly into Earth's atmosphere. Their diverging paths come from the same optical illusion that makes parallel railroad tracks appear to meet in the distance.

All meteors — "shooting stars" — are bits of dusty debris the size of sand grains or gravel, but about as tough as cigarette ash. Friction with air molecules heats them until they vaporize, making a meteor streak. The dust is blown off a comet by the solar wind, with the greatest amount ejected when it comes closest to the sun, called perihelion.

Once expelled, the dust slowly stretches into a ribbon of debris traveling nearly in the comet's orbit but meandering slightly in space. Such a dust trail can survive a dozen or more revolutions around the sun on its own. Then the gravitational influence of the planets broadens and scatters the trail, erasing its identity. Eventually what's left is a thinned-out river of particles surrounding the comet's orbit.

A fireball blazes by Orion at magnitude –8 during the 1999 Leonid shower in Norway, outshining the Hyades and Pleiades star clusters in Taurus to its right. Arne Danielsen

Darren Talbot

Alberto Levy

Alberto Levy

Michael Klensch

Michael Klensch

When Earth encounters the Leonids, it flies into this diffuse river. Within the river, roughly a dozen separate currents flow, dust trails where particles run much thicker. Each sinuous strand was exhaled from the Leonids' parent comet on one of its perihelion passages.

That comet is 55P/Tempel-Tuttle. Discovered by Wilhelm Tempel in December 1865 and independently by Horace Tuttle in January 1866, it was the 55th periodic comet to have its orbit determined. It ranges from just inside Earth's orbit to beyond that of Uranus, making one orbital revolution every 33.2 years on average. It passed through perihelion most recently in 1998.

Linking Meteors and Comets

The Leonids actually helped astronomers make the connection between comets and meteors after two spectacular storms in 1833 and 1866. The more impressive 1833 storm badly frightened people throughout eastern North America. Countless period descriptions and illustrations show Leonids flying like snowflakes in a blizzard; many onlookers were certain the world was ending. The lesser 1866 storm came shortly after the discovery of comet Tempel-Tuttle, and astronomers soon linked the two when they found they shared the same orbit.

In 1899 and 1932–33, however, the Leonids didn't storm, disappointing and puzzling eager observers. But in 1966 the Lion roared once more, mainly for skywatchers in western North America. Since then, scientists have determined that most years, we see meteors from the diffuse stream. Show-stopping storms occur when Earth passes through one or more of the threads of dust within the stream, each left like a trail of bread crumbs on one of comet Tempel-Tuttle's swings around the sun.

Leonids are among the most impressive meteors for two reasons. First, no other meteor shower's debris comes as close to Earth's orbit as that of the Leonids. Second, because Earth and the Leonids are moving in nearly opposite directions, these meteors slam into the atmosphere with terrific speed: 44 miles (71 kilometers) per second, or 159,000 miles per hour. They are actually the fastest meteors known and among the brightest.

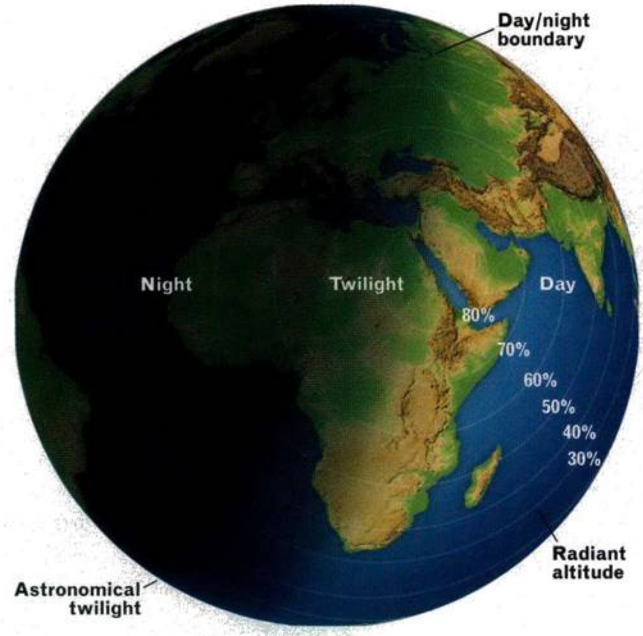
Night of the Shooting Stars

On November 18 to 19, Earth collides head-on with two Leonid dust trails. The first was shed by Tempel-Tuttle in 1767, seven orbital revolutions ago. The second dates from 1866, four revolutions ago.

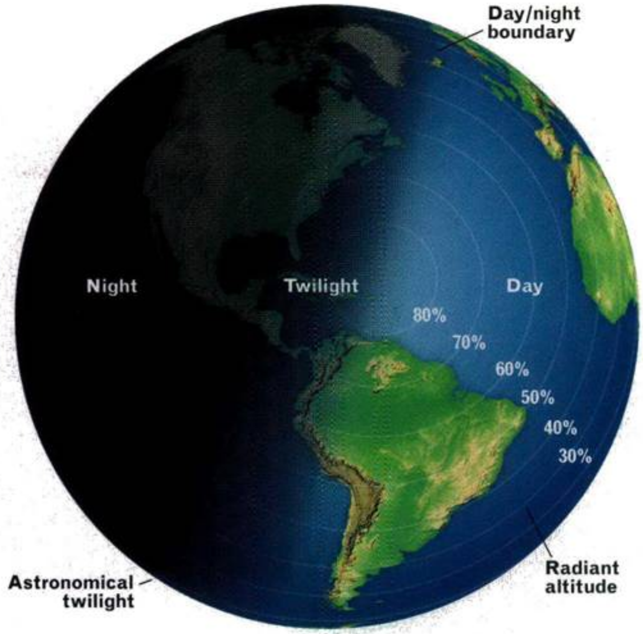
Meteors from the 1767 stream will peak around 04:00 Universal Time (UT) on November 19. To convert UT to EST, subtract 5 hours, changing the date if necessary. Subtract 6 hours for CST, and so on. This works out to 11 P.M. EST on the 18th.

Left: Meteors, like snowflakes, are all distinctive. The brightest, such as the one below, are called fireballs and can cast eerie shadows on the ground. Fireballs that seem to explode are known as bolides.

Left: Michael Klensch; below: Darren Talbot


Day/night boundary
Night
Twilight
Day
80%
70%
60%
50%
40%
30%
Radiant altitude
Astronomical twilight

At 04:00 UT on November 19, the side of Earth shown above will slam into the first of two thick dust trails, shed by comet Tempel-Tuttle in 1767. Only those under cover of night will be able to see the storm, and the best views will occur where the radiant is highest in the sky .


Day/night boundary
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Twilight
Day
80%
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Radiant altitude
Astronomical twilight

About six hours later, Earth will hit another dust trail (this one sloughed off in 1866). The planet will have rotated so that the Americas will get a chance to see the show. Twilight will wash out fainter meteors.

Illustrations this page: *Astronomy*: Elisabeth Rowan

Four hours UT is ideal for sites in Europe and Africa, where the radiant will be high in the southeast near Jupiter. In the west, the moon, less than a day before full, will be descending, its light somewhat dimmed. Weather permitting, the sight of countless Leonids streaking through the sky should be splendidly unforgettable.

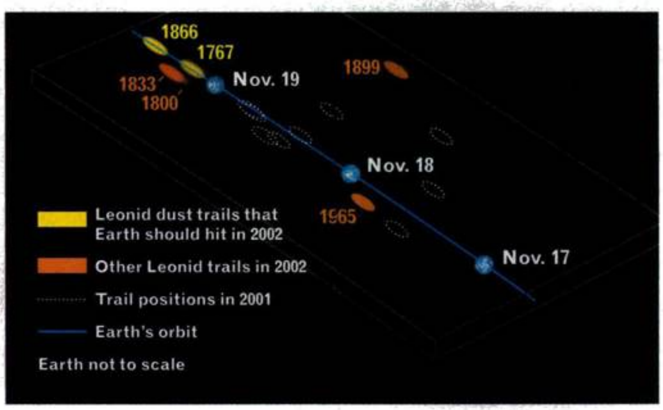
But while the radiant will be visible in parts of northeastern North America, the timing is poor. The radiant will lie very low in the northeast with about half the meteors racing below the horizon unseen. Moreover, the moon will stand high in the south, brightening the sky overall.

Then, more than six hours after the first storm's peak, Earth plunges into the 1866 dust trail, centered around 10:30 UT. This works out to be 5:30 A.M. EST on the 19th. By now it's full daylight in Europe, Africa, and South America, but darkness still holds over North and Central America. Leo stands high in the southeast and the moon lies well in the west, its dimmed light offering less hindrance. Only dawn will end the show.

The lunar phase falls within a day of full and moonlight will certainly wash out the fainter meteors. Depending on how hazy your sky is, expect to lose most Leonids dimmer than about 3rd magnitude. This is unfortunate, but it is not a disaster because the Leonids also include many bright meteors.

How rich will the display be? This is never easy to answer, but meteor scientists have recently developed better dust-trail models. The number of meteors seen in one hour by an observer under dark, moonless skies with the radiant overhead is known as the zenithal hourly rate (ZHR). It's idealized, since real observers almost never have it that good, but it remains the standard gauge. David Asher of the Armagh Observatory in Northern Ireland and Rob McNaught of the Anglo-Australian Observatory estimate that the 1767 stream will produce a ZHR of 1,000 to 2,000, while the 1866 dust will net 3,000 or so.

Another team in the ZHR-calculating game includes Esko Lyytinen and Markku Nissinen of Finland's URSA Astronomical Association, and astronomer Tom Van Flandern of Meta Research, near Washington, D.C. They propose ZHRs of 3,500


1866
1767
1833
1800
Nov. 19
1899
Nov. 18
1965
Nov. 17
Leonid dust trails that Earth should hit in 2002
Other Leonid trails in 2002
Trail positions in 2001
Earth's orbit
Earth not to scale

Comet Tempel-Tuttle leaves a fresh dust trail every time it swings around the sun — this month we're due to hit two. Inclined to the plane of Earth's orbit by about 17°, the trails (shown in cross section) shift annually due to tugs from the planets (last year's locations have dotted outlines).

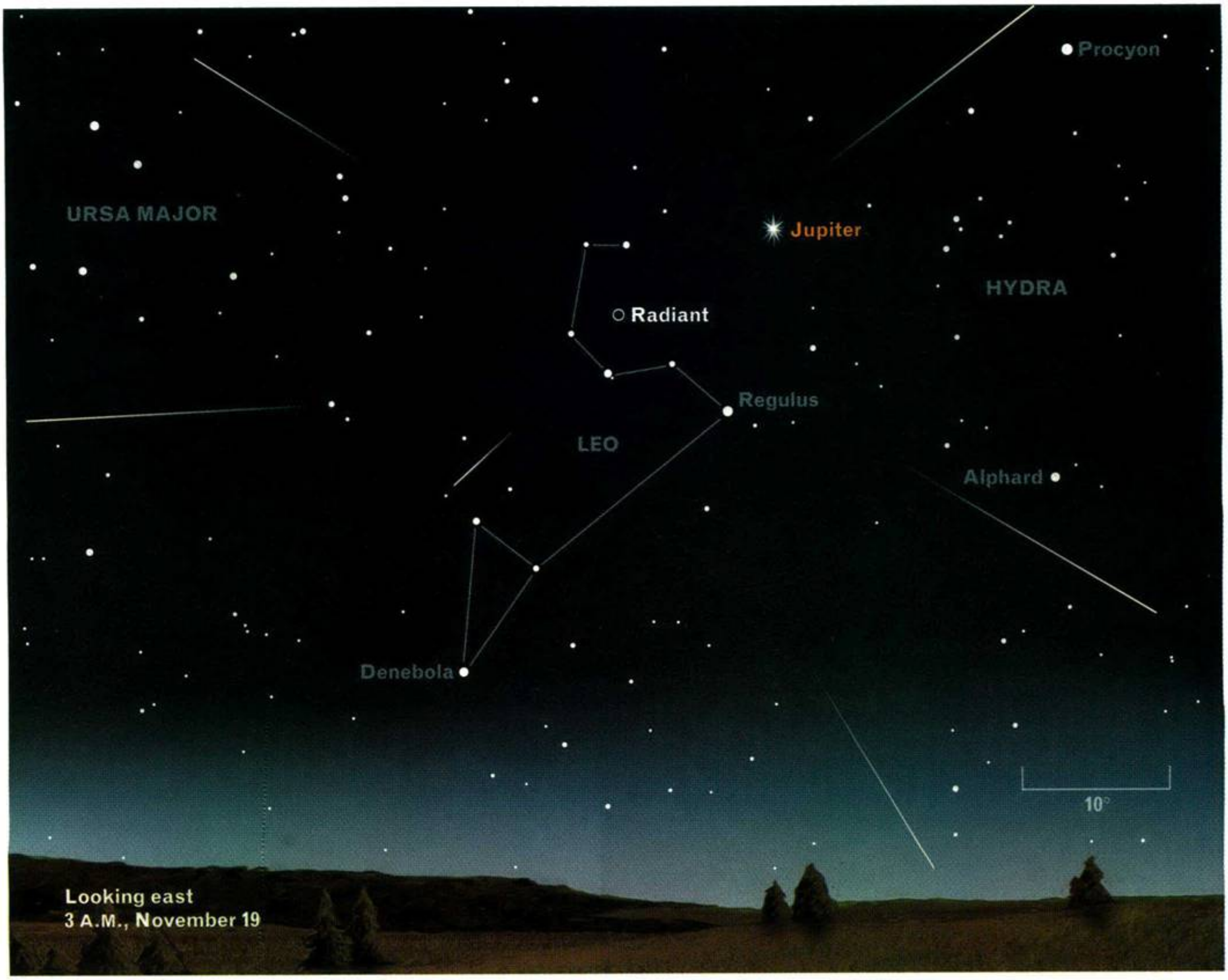
Leonid Links

Online:

American Meteor Society
www.amsmeteors.org
Armagh Observatory Leonid page
www.arm.ac.uk/leonid
International Meteor Organization
www.imo.net
NASA's Leonid MAC Project
leonid.arc.nasa.gov
North American Meteor Network
www.namnmeteors.org

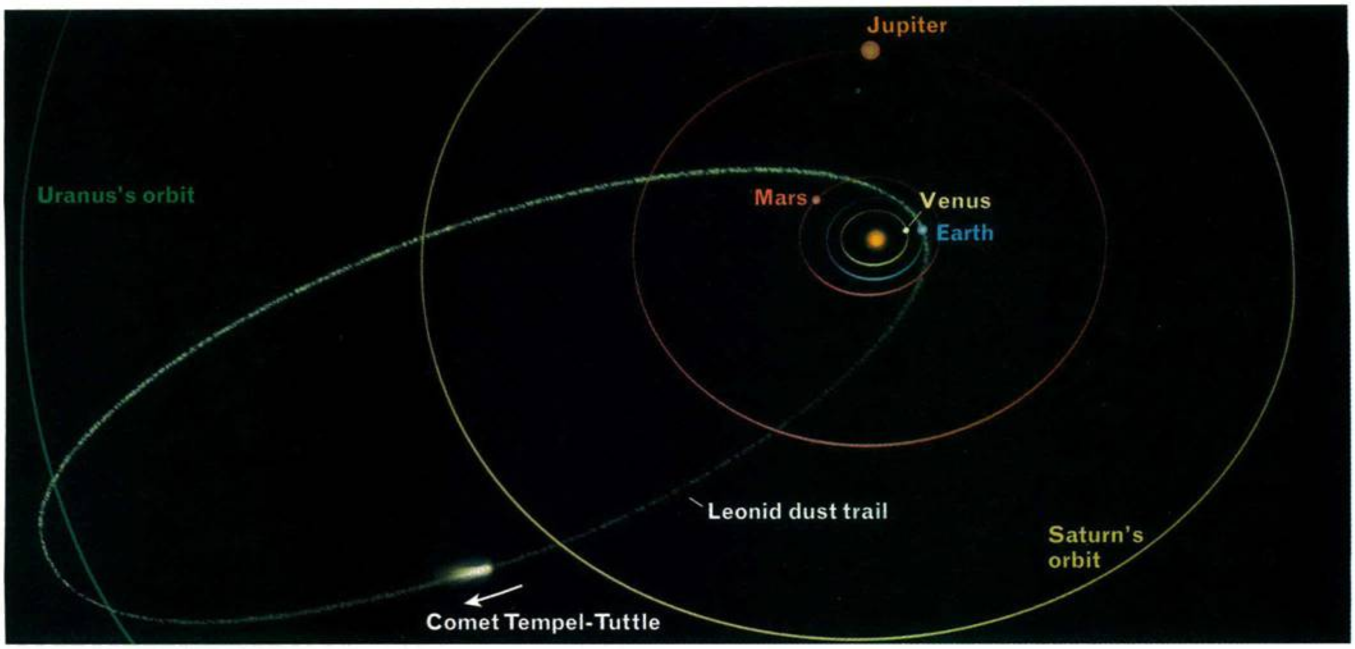
In print:

The Heavens on Fire: The Great Leonid Meteor Storms, Mark Littmann; Cambridge University Press, New York, 1998


Procyon
URSA MAJOR
Jupiter
HYDRA
Radiant
Regulus
LEO
Alphard
Denebola
10°
Looking east
3 A.M., November 19

Above: Don't miss the chance to see the Leonids storm. Meteors will appear to emerge from a point in the sky called the radiant, which is located in the constellation Leo. *Astronomy*: Elisabeth Rowan

Below: Every November, Earth crosses comet Tempel-Tuttle's orbit, which takes about 33 years to complete. Because of the solar wind, the comet's tail always points away from the sun. *Astronomy*: Elisabeth Rowan


Jupiter
Uranus's orbit
Mars
Venus
Earth
Leonid dust trail
Saturn's orbit
Comet Tempel-Tuttle

and 2,600 respectively, at peak times of 04:10 UT and 10:46 UT.

Peter Jenniskens of California's SETI Institute heads the Leonid Multi-Instrument Aircraft Campaign project at NASA's Ames Research Center. In it, high-flying aircraft bounce radar signals off the meteors' ionized trails. Jenniskens estimates ZHRs of about 4,000 at 04:07 UT and 5,000 at 10:13 UT.

Past experience shows that storms have narrow periods of high activity, only an hour or so long. The storm's most spectacular part may last only 10 or 15 minutes, with meteors coming in brief bursts. For backyard skygazers, differences among the estimates are largely moot. The proper course of action is simple — be outdoors and be ready.

Hunting for Leonids

Observing Leonids is pretty low-tech. Find an observing site with skies free of urban lights, especially toward the east. This helps, even with a bright moon.

Second, get comfortable. Bring a lawn chair or something you can recline on. Several hours outdoors with little activity lies ahead, so dress in layers and wear more than you think you'll need. A big thermos of something hot will be mighty welcome as the night rolls on. If possible, convince at least one friend or family member to go with you. Each of you can then cover different parts of the sky. And having company keeps everyone awake and alert.

Leave telescopes at home — meteors are best appreciated with the naked eye because they cover such a large portion of the sky. Thinking about photos? See "Shoot a Shooting Star" at right. Dedicated meteor watchers will bring red flashlights to preserve their eyes' adaptation to the dark and hourly meteor-count forms marked off in 5- or 10-minute intervals.

A tape recorder and time-signal radio might also make handy accessories — over centuries people have reported hisses, whooshes, pops, and sizzles from meteors. These sounds remain largely mysterious, but may occur when very low-frequency radio waves generated by the meteors cause something near an observer to vibrate.

Observers classify meteors by stellar magnitude, but novices often find it hard to say just how bright one was. Guesstimate using benchmarks: Jupiter shines at magnitude –2.2, Sirius at –1.4, and Rigel at 0.1.

Weather prospects looking iffy? Go anyway. Clear intervals often occur, and even a few clouds won't completely hide the brightest Leonids. If time permits, travel to a dark-sky site in eastern North America that is relatively elevated and dry (to reduce moonlight-scattering haze). From there the radiant will be higher and the moon lower and dimmer.

Finally, place yourself in a pool of moon-shadow: Face somewhat away from the radiant for longer and more impressive meteors, then, settle back and enjoy the show.

Earth encounters no Tempel-Tuttle dust trails during the next few years, although ordinary Leonid displays will occur. Predictions call for an encounter with the 1932 dust trail in 2006. The timing favors western Europe and Africa, and the moon will be new. But according to Asher and McNaught, the ZHR is a measly 100, far below storm levels.

So November 2002 really is your last chance for big-time Leonids — until around 2033. Don't let this rare opportunity pass you by.

Robert Burnham has written many astronomy books. His latest, Exploring the Starry Sky, *will soon be published by Cambridge University Press.*

Shoot a Shooting Star

Taking meteor photos on film is pretty simple. Get a camera that lets you set the exposure time (a B- or T-shutter setting) and control the focus and aperture (f/stop) of the lens — SLRs do this better than point-and-shoot models. Choose a normal or wide-angle lens; avoid zooms.

Use ISO 400 or faster film. Slides encounter fewer problems in processing, but many people prefer prints. Have them processed locally and be sure to explain the subject matter. (A normal scene at the head of the roll helps the processer cut the frames correctly.)

Mount the camera on a tripod, focus on infinity, and open the aperture to the lowest f/number. For nice long meteor trails, aim 60° away from the radiant. Then open the shutter.

Accurately timed photos can contribute to meteor science. Set your watch by calling (900) 410-8463, and record the exposure starting times to one second. In moonlit skies, keep exposures under five minutes to prevent overexposing the film. When a bright meteor zooms through the camera's field of view, end the exposure and start another.

Long exposures in digital cameras draw down the battery during the entire shot and it soon goes flat. But exposures up to 30 seconds or a minute work fine, and if Leonids are storming you'll capture some. Turn off the flash, and set the lens at wide-angle and full aperture.

Put a video camera on a tripod, aim 60° off the radiant, and let it run. (Extended play saves tape but degrades images appreciably.) Use a normal or wide-angle lens. Have lots of extra tape and batteries, or a plug-in power source. Beware of dew or frost on the lens. — *R.B.*

Since the Leonids' paths are unpredictable, they are best viewed with the naked eye, which offers the widest possible field of view. Ron Zincone

It Came From

Recent observational evidence supports the theory that the chemical stew necessary for the development of earthly life was imported from space.

by Joe Alper

If the fossil record is correct, primitive life appeared on Earth no more than 100 million years after the end of the 500 million-year period of sterilizing, cataclysmic bombardments that shaped our newborn planet. A blink of an eye, really — a time frame that makes it almost impossible to imagine earthly life getting its start nearly 4 billion years ago without some outside help.

But probably not in the way that likely popped into your mind. Life did not arrive from space. No microbes on meteorites. No panspermia.

But what did likely come from space were the chemical building blocks of primitive life. "One hundred million years just seems a little short to allow for the creation of both the chemicals of life and life itself, but there wasn't a need for those chemicals to be synthesized here on Earth," asserts astrophysicist Scott Sandford, of NASA's Ames Research Center at Moffet Field in northern California. "Instead, those building blocks were probably part of the enormous tonnage of organic chemicals that arrived during the period of heavy bombardment and that continue to arrive from space even to this day."

That's right. The billions of dust grains that speckle our planet every day dump roughly the weight of three school buses (30 tons, or 27.2 metric tons) of organic debris — stuff with carbon atoms bonded to hydrogen, oxygen, and nitrogen atoms — into Earth's upper atmosphere. The universe, it seems, provides a series of chemical refineries from the build-up of ever heavier elements in stellar nuclear furnaces to the molecular molding that occurs in the interstellar medium. In fact, says physicist-turned astrochemist Hugh Hill of NASA's Goddard Space Flight Center in Greenbelt, Maryland, "the diversity of chemicals made in space arises in most instances from the exact chemistry that we use in petrochemical processes on Earth to make complex organic molecules."

Indeed, evidence collected over the past decade from a wide range of earthly and stellar sources indicates that space is a place that can't help but make organic chemicals. The implications of this are profound, says Jeffrey Bada, a geochemist at the Scripps Institution of Oceanography in La Jolla, California. "Organic chemistry is ubiquitous in the universe, which suggests that if extraterrestrial sources seeded the early Earth with complex organic chemicals, then the same process is likely to be taking place wherever you have planet formation."

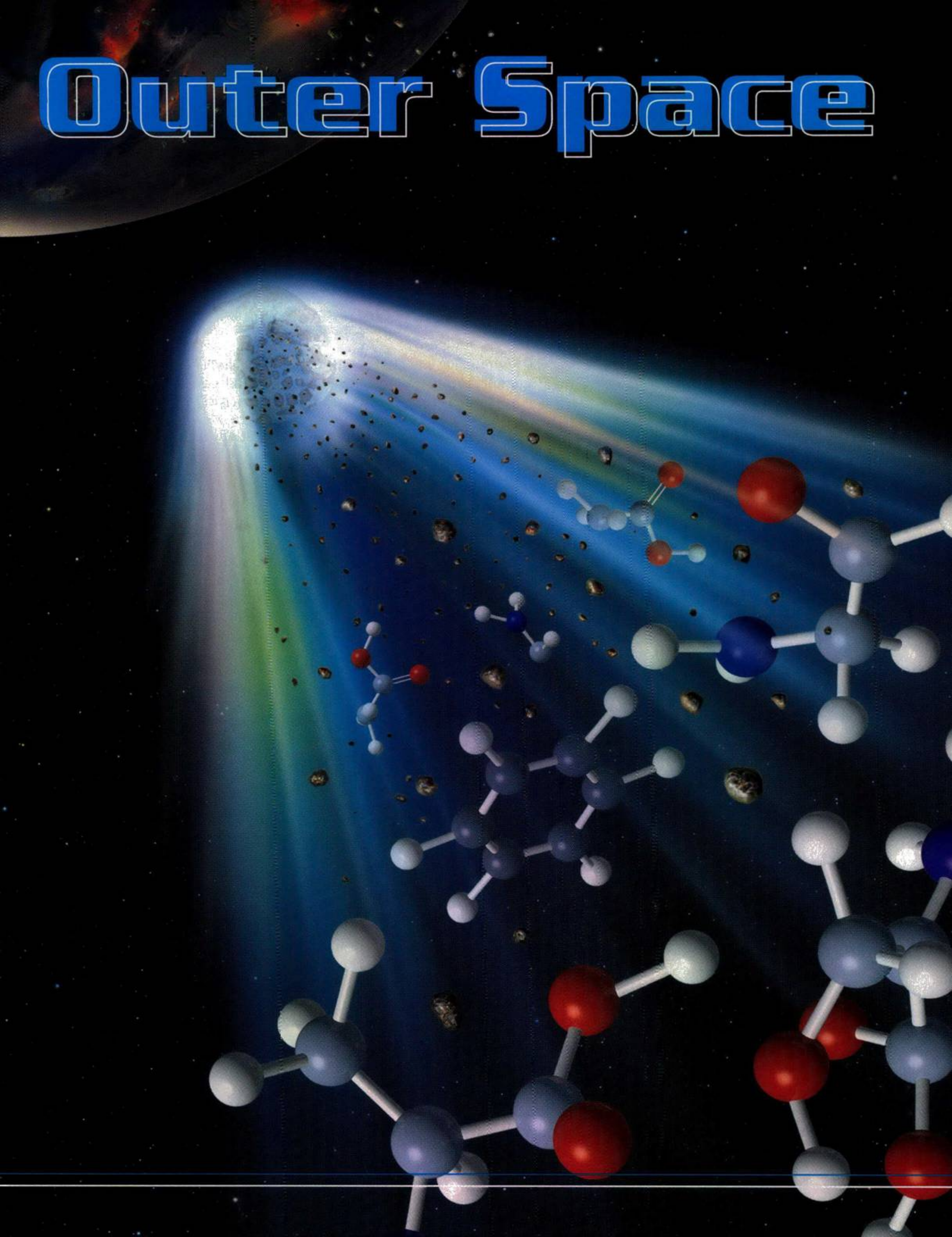
In other words, just as organic chemistry appears to be a constant in the universe, so too might the ability for life to arise. "The jump from organic chemicals to life is huge, but if molecules from space had something to do with the development of life here, then that means they're always available to help with the development of life wherever suitable conditions exist in the universe," says Sandford.

Cooking Up a Chemical Stew

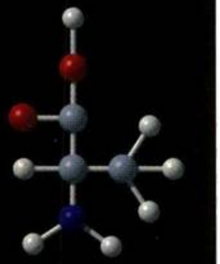
In 1953, two University of Chicago chemists came up with a different, potentially universal explanation for how the chemicals of life could arise on a primordial planet such as Earth in its early days. Two years earlier graduate student Stanley Miller heard a lecture by Harold Urey in which the Nobel laureate suggested the chemicals of life could have arisen on Earth through chemical reactions sparked by lightning. Intrigued by the idea, Miller volunteered to run such an experiment with Urey's guidance.

At the time, scientists believed Earth's early atmosphere was "reducing;" that it was composed of hydrogen-rich chemicals such as methane, ammonia, water, and molecular hydrogen, but devoid of molecular oxygen. Using such a mixture as a primordial atmosphere, Miller set up a closed reaction apparatus in which a flask of boiling water stood in for Earth's early ocean, and a pair of electrodes provided the "lightning." After a few days of lightning strikes, Miller's ocean had become a murky brown, so he stopped the experiment and analyzed the water, only to find large amounts of amino acids in the soup. Other experiments by Miller and Urey, as well as by the then-young Carl Sagan, showed that ultraviolet light

Outer Space

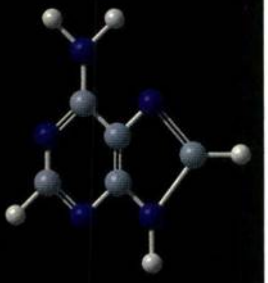


Amino Acids



One of the 20 amino acids that build proteins, alanine is an important source of energy, strengthens the immune system, and helps with metabolism.

Nucleic Acids



Nucleic acids carry hereditary information and are essential components of all living cells. Adenine is a constituent of the nucleic acids DNA and RNA.

KEY

● Oxygen atom

● Hydrogen atom

● Nitrogen atom

● Carbon atom

Left: An artistic depiction of the Tagish Lake fireball. UWO
Right: A fragment of the Tagish Lake meteorite embedded in ice, making it one of the most pristine such samples ever. UWO

could replace lightning — a handy experimental twist because planetary scientists were beginning to think that lightning wasn't very common in Earth's early days. Further tinkering with experimental conditions yielded a menagerie of biomolecules such as sugars, nucleic acids, and porphyrins — a major component of blood's oxygen-carrying protein hemoglobin.

Most surprising was how easy these results were to obtain, suggesting that Miller-Urey chemistry could jump-start life under a great variety of conditions. But recent evidence suggests that the early atmospheres of our solar system's inner planets, at least, were never reducing. "If Earth's early atmosphere wasn't reducing, and we really don't think it was, then this chemistry could have never occurred," explains Joseph Nuth III, a chemist at Goddard.

That's not to say, though, that the Miller-Urey conditions couldn't occur somewhere in the universe, or even over some parts of early Earth. "I'm not completely convinced that there weren't Miller-Urey conditions here on Earth, particularly in the vicinity of volcanoes, which probably spewed out methane and ammonia," says Bada. "But if you look at the kinds of organic compounds we find in at least some meteorites, then you have to assume that Miller-Urey type chemistry is occurring somewhere in the interstellar medium because the types of compounds — amino acids and the like — and the amounts of those compounds are strikingly similar."

There is, however, a more serious problem with Miller-Urey type experiments, at least as far as the origin of life on Earth is concerned — they generate only what are known as racemic mixtures of the amino acids. Each amino acid, except for glycine, occurs in two versions that mirror each other's shape, in the same way that our hands are identical but mirror images of each other. All living creatures on Earth use left-handed amino acids to make proteins, but the Miller-Urey experiments produce equal amounts of both forms — a so-called racemic mixture. And while Miller, now a chemist at the University of California, San Diego, believes early life somehow selected one form over the other at some point during evolution, nobody has yet been able to demonstrate how this might have occurred.

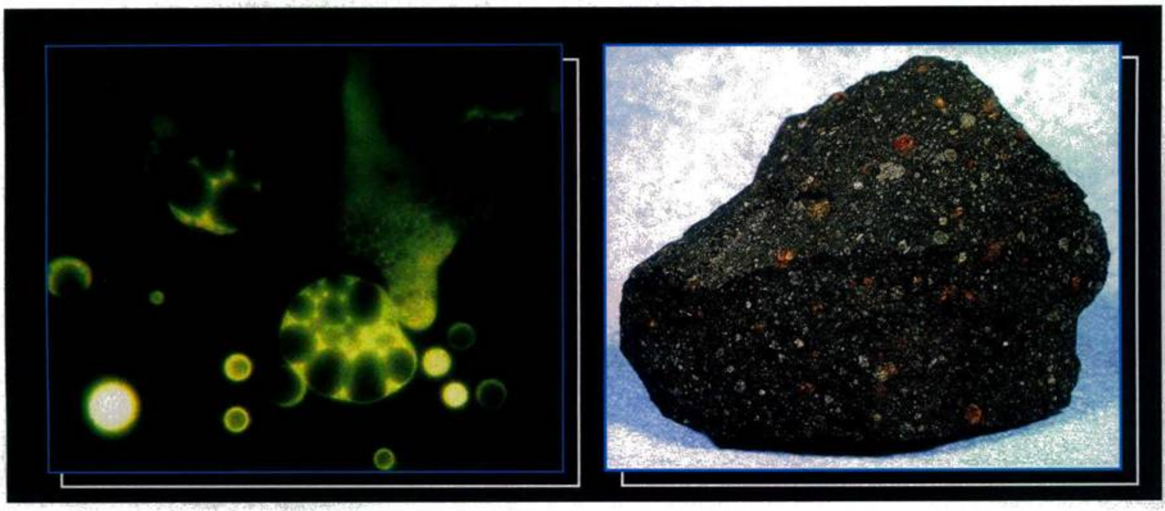
However, amino acids from other sources — space, perhaps — may have already had such bias. If so, the deck might have been stacked in favor of molecular left-handedness.

All the Stuff of Life from Space

From the earliest days of radio astronomy, astronomers have increasingly observed complex chemicals. At first came simple atoms and molecules, such as hydrogen and helium, carbon and iron, aluminum chloride, and magnesium oxide. But as astrochemists looked further, the list took on a decidedly lopsided look, with molecules containing carbon, hydrogen, oxygen, and nitrogen predominating. And by the time researchers started identifying molecules with seven or more atoms, the list became exclusively organic in nature, just as it is for larger molecules here on Earth.

Today, the list of chemicals detected in space ranges from the amino acid glycine up to complex polycyclic aromatic hydrocarbons (PAHs) similar to those found in coal or heavy petroleum. Astronomers identify these molecules based on their ability to absorb infrared radiation at discrete frequencies. The PAHs, for example, account for what was once known as the Unidentified Infrared Bands (UIBs), a collection of spikes in the infrared spectrum first noted in 1973. Lou Allamandola and his colleagues at NASA–Ames have spent nearly 20 years pinning down the true identity of UIBs as PAHs through a combination of laboratory syntheses, theoretical predictions, and interstellar observations.

In addition, researchers have isolated a wealth of organic compounds from meteorites, particularly the 4.6 billion-year-old Murchison meteorite, which fell in Australia in 1969, and the similarly aged Orgueil meteorite that struck France in 1864. The compounds obtained from meteorites include almost all of the amino acids found in earthly life, as well as many more that aren't found in Earth's biosphere. They also contain nucleic acids (the building blocks of our genes) and a host of other biologically important compounds such as ketones, carboxylic acids, amines, amides, and quinones — a great variety of organics



Membranous vesicles (left) formed from UV irradiation of organic residues from this 4.5-gram sample of the Murchison meteorite (right). David Deamer/UCSC

vital to biochemical reactions.

In 2001 researchers fleshed out the list with the discovery of two additional biomolecules — sugars and pyridine dicarboxylic acids, which are also critical biomolecules. To find sugars, geochemist George Cooper and his colleagues at NASA–Ames use a combination of techniques known as gas chromatography and mass spectroscopy to analyze water extracts of pristine samples removed from the interior of the Murchison meteorite. Gas chromatography separates a complex blend of chemicals into its constituents, while mass spectroscopy yields the identity of each component. The results obtained with these tools show clearly that the meteorites contain many different types of sugars and related compounds known as poly-alcohols, or polyols, at about the same concentrations as the amino acids found in these same meteorites. The researchers also found that the relative amounts of heavy to light carbon and hydrogen atoms — the C13/C12 and deuterium/hydrogen ratios — in the sugars revealed that these molecules came to Earth as part of the meteorite and were not contaminants. These ratios are significantly higher in molecules that originated in the interstellar medium compared to those made on Earth.

Cooper was also part of a team led by Sandra Pizzarello, a chemist at Arizona State University, which has examined samples from a more recent arrival on Earth. On January 18, 2000, at about 8:45 A.M. local time, an asteroid or comet broke up in the sky over British Columbia and showered some 500 fragments onto Tagish Lake in the northern reaches of the province. The Tagish Lake meteorite fragments are a treasure to astrochemists because many pieces were frozen solid in the ice sheet above the water and recovered just a week later by amateur geologist Jim Brook. After finding big pieces of ice containing meteorite fragments, Brook was careful not to handle them with his bare hands, and kept them frozen until he could turn them over to the proper authorities. "This was a very significant find, certainly the most pristine, and we were quite anxious to look at the organic materials in the meteorite," says Pizzarello.

The Tagish Lake meteorite — like both Murchison and Orgueil — belongs to an ancient family of meteorites known as carbonaceous chondrites. These primitive meteorites contain significant amounts of carbon and are thought to provide a snapshot of what our little corner of the universe was like at the time the sun and solar system were forming. Pizzarello, known for her analysis of amino acids in meteorites, was able to procure a pristine 4.5-gram fragment. Together with Cooper and colleagues from NASA, Brown University and the University of Rochester, she identified the organic content of the Tagish Lake meteorite, though not, says Pizzarello, "without a great deal more difficulty than we expected. The analysis has been a hellish ride."

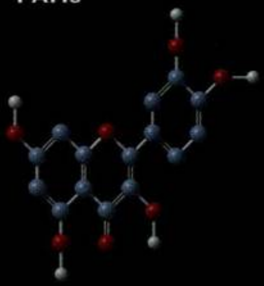
She was shocked by the initial data. "We expected the results from Tagish Lake to look like those from Murchison and Orgueil, but when we looked for amino acids we found almost nothing, and when we looked further for amines and carboxylic acids that are quite abundant in Murchison, we found almost nothing again. I thought this was the biggest letdown of my life," she says.

But then pleasant surprises started coming. "First we found dicarboxylic acids at about the same abundance as we see in Murchison, which is odd because we've always thought that the same chemistry that generates the amino acids in Murchison would have made the dicarboxylic acids," explains Pizzarello. "And then we started finding entire new classes of biologically important molecules, such as phenyl dicarboxylic acids and pyridine derivatives such as nicotinic acid." Carbon isotope analysis confirmed that these molecules were indeed created in space, not on Earth.

The Tagish Lake meteorite appears to have preserved organics that accumulated or developed in the early history of the solar system — including bubble-like molecules of pure carbon (fullerenes or "buckyballs") containing the noble gases helium and argon, which exist in ratios not found in any terrestrial sources but in relative quantities similar to those found in interstellar gas and dust clouds — and therefore may reflect an early stage of the evolution of complex carbon compounds in space.

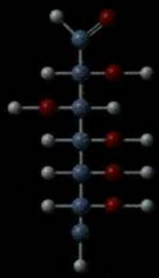
"This is really quite important because it's quite clear that the chemistry of the Tagish Lake meteorite

PAHs



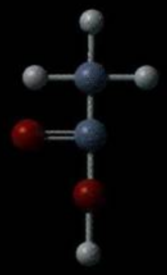
Naphthalene is among a group of chemicals called polycyclic aromatic hydrocarbons (PAHs), which are very stable organic molecules made up of carbon and hydrogen. Highly carcinogenic but common on Earth, PAHs likely explain some unusual observations of interstellar space.

Sugars



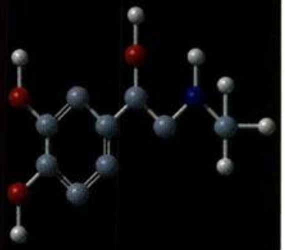
Glucose is a common form of sugar, which provides organisms with energy. Created by photosynthesis, glucose is used in cellular respiration (the process of obtaining energy from food).

Carboxylic Acids



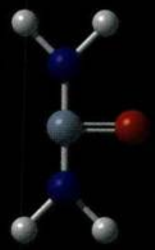
Carboxylic acids are weak acids that occur naturally in many organisms and are primary components of DNA. An example is acetic acid, the principal component of vinegar.

Amines



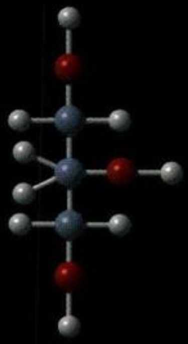
Amines are organic compounds derived from ammonia. An amine compound called epinephrine (or adrenaline) is a hormone released into the bloodstream in response to certain stimuli.

Amides

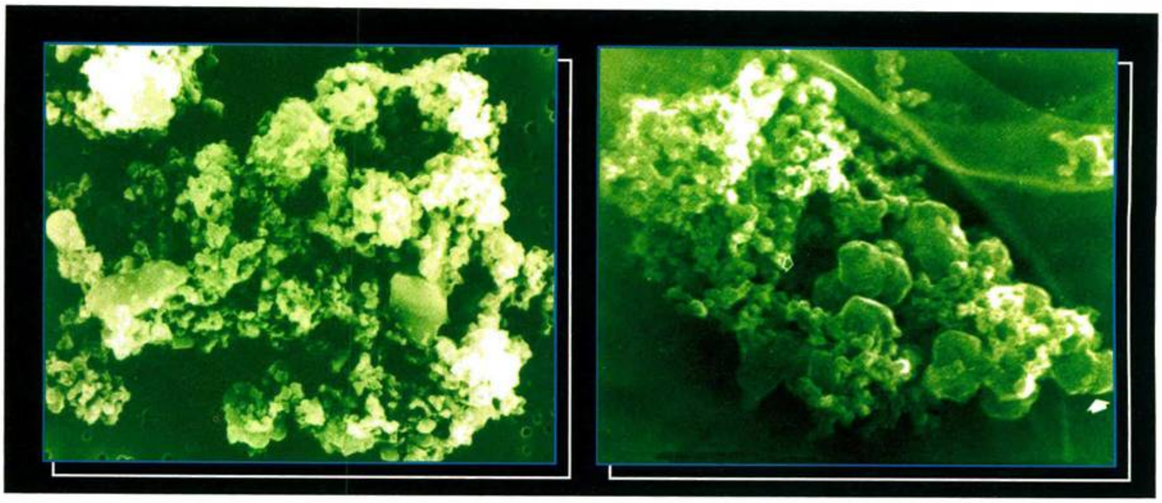


Like amines, amides are organic compounds derived from ammonia. An amide called urea is the main product of nitrogen metabolism in most mammals.

Polyhydric Alcohols



Alcohol molecules contain a hydroxyl (OH) group, and polyhydric alcohols have more than one. A trihydric alcohol, glycerol is present in all animal fats and oils.



Left: Naturally occurring interplanetary dust particle (IDP) upon which organic chemical reactions are thought to occur. Right: An artificially constructed IDP at NASA-Goddard

is different from that of Murchison or any of the other meteorites we've studied so far, meaning that Tagish Lake and these other meteorites formed in different interstellar environments," says Pizzarello. "Our theories of how chemistry takes place [in space] are too general. We need to do some more thinking."

Looking for that Spark

In retrospect, admits Pizzarello, perhaps it should not have come as such a surprise that there might be different mixes of organic compounds made in various interstellar environments. After all, in earthly laboratories small changes in conditions can alter the outcome of most chemical reactions, so the same should be true in space, where chemistry could be happening in environments as diverse as within huge dust clouds or in the immediate vicinity of a newly forming star.

The one thing that nearly all environments would require is enough energy to drive chemical reactions. On Earth most chemical reactions are powered by heat, but based on the results of laboratory experiments, ultraviolet radiation serves the same purpose in the cold of space — even better, since it's a higher energy source.

In the astrochemistry lab at NASA–Ames, Jason Dworkin and colleagues have shown that ultraviolet radiation can power a set of chemical reactions with a surprising outcome. Working at temperatures around 15° above absolute zero (–431° F or –257° C), Dworkin created an interstellar ice analog from a mixture of water, methanol, ammonia and carbon monoxide similar to that found in comets. He then irradiated the mixture with ultraviolet light for two days, which left an oily residue on the surface of the reaction vessel. Assuming his organic goop would contain the usual mix of water-soluble organic compounds that other researchers have created in similar experiments, he dissolved the residue in water and found something unusual — droplets formed. Further analysis showed these droplets were actually tiny circles comprising molecules with a water-soluble head and an oily tail, the same kind of molecules that come together to form cell membranes in all creatures on Earth except viruses. In essence, the NASA–Ames team had shown that a fundamental structure of life, a membrane, could form from chemicals made in the cold of interstellar space.

"This was a remarkable result," says Sandford, who worked with Dworkin on this study. "But it's really just an extension of what we've produced in every mixed ice experiment we've run, which clearly shows that mixtures of simple starting materials can react to make hundreds of new chemicals under the conditions seen in interstellar space," says Sandford.

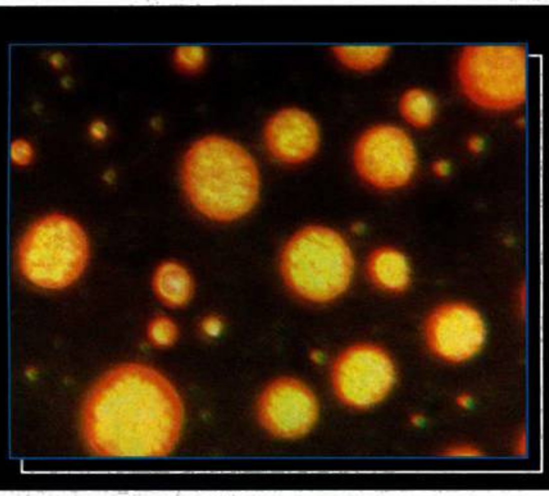
Chemical cookeries might also happen independent of light-driven reactions. At NASA–Goddard, for example, Hugh Hill and Joe Nuth have been doing chemistry on homemade interstellar dust grains designed to resemble the dust that condenses in the cool atmospheres of old stars. The two chemists make the dust by shooting a cocktail of chemicals through a furnace, where a fluffy "astrophysical dust grain analog" rapidly condenses. "Once we had this silicate dust, we wondered if the metal atoms on the surface of these particles could catalyze chemistry, just as metal atoms catalyze chemistry in the lab," explains Hill.

Several experiments later, with a variety of gaseous mixtures as starting materials, the answer was a resounding yes. "We made amazingly complex mixtures of chemicals, including lots of nitrogen-containing compounds, which in overall terms were quite similar to the complex suite of organics you see in meteorites," says Hill, "and since we didn't have an energy source, the metal atoms on the surface of these particles must have been acting as catalysts."

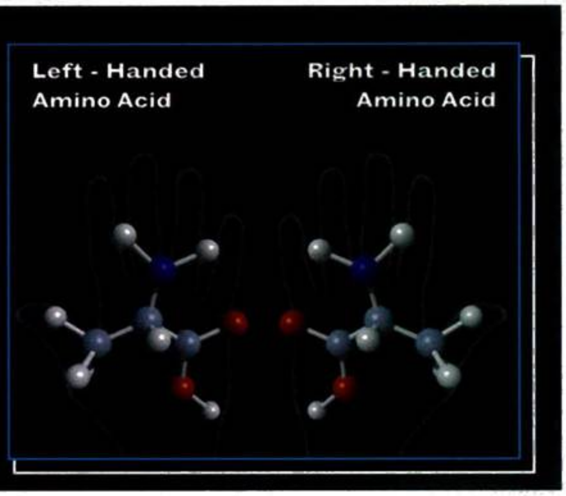
Pick a Hand

There seems to be little doubt that the dust-filled reaches of space can provide an environment ripe for organic chemistry to take place. There is also good evidence, based on work in many laboratories and from telescopic observations, that dust laden with organics can find its way into comets and other large and small interstellar bodies. These objects then act as chemical shuttles that deliver their payloads to developing and established planets. Taken together, these findings provide good reason to think that the chemicals of life could have come from deep space.

But there's *still* the issue of handedness, of why life on Earth so overwhelmingly chose left-handed



NASA's Dworkin created these cell-like vesicles from scratch.



Earthly life-forms function only with left-handed biomolecules.

All Illustrations *Astronomy*: Elisabeth Rowan

over right-handed molecules. Living organisms have evolved so that they use only left-handed amino acids when they make proteins, but that's because nature makes only left-handed amino acids. It's the classic chicken-and-the-egg question: Did life evolve to use only left-handed amino acids, causing the right-handed forms to gradually fade away, or did life evolve to use left-handed amino acids because those were the most prevalent when life got its start?

If Miller and Urey had been correct, nature would have driven this selective pressure on molecular shape. However, the amino acids in meteorites turn out not to be racemic mixtures. Instead, the left-handed forms predominate — what is known as enantiomeric excess — suggesting that the molecules drove nature's evolution. This evidence comes primarily from work done by Pizzarello, who says this is one of the most important issues when it comes to talking about chemical evolution. "Yes, we find enantiomeric excesses in meteorites, but now we have to explain how that might happen out in the conditions of interstellar space."

Indeed, this is one of the great questions before astrochemists these days. For a few years, it appeared that the natural polarization of ultraviolet light in interstellar space could drive chemistry to favor left-handedness over right-handedness, but recently Pizzarello has found enantiomeric excesses much higher than is theoretically possible with polarized light as the leading factor. One new possibility is that asymmetry results from the metal-catalyzed reactions that occur on dust grains, an idea supported by Hill and Nuth's work, as well as by experiments that Pizzarello and her colleagues perform. For now, at least, space-formed molecules may have tilted the balance at life's beginning, but everyone in the field still considers this an open-ended question.

An Earthly Explanation

That's not to say that everyone agrees that all vital organic chemicals came from space, like manna from heaven. Geophysicist Friedemann Freund, a staff scientist at the SETI Institute who spends most of his time at NASA–Ames, is one who thinks he has found a closer source of biological molecules — the magma that flows from volcanoes. Freund has studied the chemistry of microscopic impurities trapped in magma as it crystallizes after a volcanic eruption and detected the characteristic infrared signature of organic compounds. In addition, he has found tiny amounts of water trapped within the magnesium oxide crystals in magma, a somewhat surprising finding but important, he thinks, for the production of organics within cooling magma.

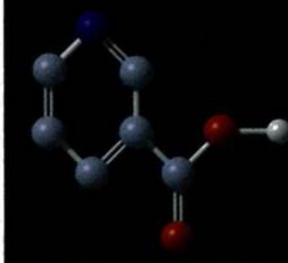
"Within the crystal structure, water can act as a source of peroxide, which can react with trapped carbon dioxide and hydrogen gas to create simple organics," explains Freund, who has done theoretical modeling and laboratory experiments to show this is plausible. He also proposes that as the cooled magma erodes through normal weathering processes, these simple hydrocarbons would react with one another in the presence of the metal-laden crystals acting as catalysts to produce larger, more complex organics. A preference of left-handedness over right-handedness could have resulted, he says, in much the same way that it might arise from metal-catalyzed reactions in space. "And since a significant amount of volcanic rock erodes each year," argues Freund, "magma could have provided just as much organic material to the prebiotic chemical soup as space-generated organics." In fact, Freund suspects that earthly life got its start thanks to a dual contribution of interstellar and magma-generated organics.

Making the Leap

Did life on Earth get a boost from the stars? While it's impossible to say for certain, researchers do feel confident in drawing one conclusion from these and other studies. "The diversity of organic compounds that we find everywhere we look makes it reasonable to assume that if life has developed elsewhere in the universe, it's likely to be based on pretty much the same biochemistry that has evolved here on Earth," says Sandford. But as Hill cautions, "Creating a prebiotic soup seems fairly easy. But making the leap to life is a huge one." ■

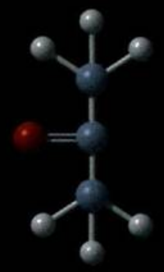
Joe Alper is a veteran science writer and regularly contributes to magazines such as Science *and* Astronomy.

Pyridine Derivatives



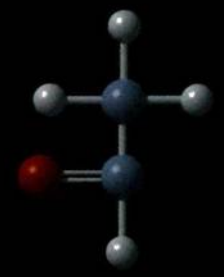
Pyridine is a water-soluble liquid and the parent of many biologically important compounds. A deficiency of one derivative called nicotinic acid (or niacin) causes the disease pellagra.

Ketones



Ketones are organic compounds that contain a carbonyl (CO) group. Acetone, the simplest ketone, is an intermediate product of metabolism and is found in abnormal amounts in the urine of diabetics.

Aldehydes



Chemically more active than their ketone cousins, aldehydes are derived from alcohols. Those with low molecular weights, such as acetaldehyde (which is used as a preservative), have repellent odors.

Unveiling the

A new telescope promises to nail down the distribution of dark matter.

by Ray Villard

Virtually all our understanding of the universe is built on "pedestals of light." Yet the glow of gas, stars, and galaxies has skewed our view in much the same way that someone flying at night can only guess at the topography of the ground below from seeing the lights of towns and cities.

Astronomers now realize those pedestals are embedded in an intangible bedrock called dark matter, which accounts for 30 percent of the stuff of the universe. Add to that the even stranger realization that a repulsive form of gravity — dubbed dark energy — may be pushing galaxies apart while accounting for 65 percent of the energy content of the universe. The light comes from ordinary matter, which makes up less than 5 percent of the mass-energy content of the universe. That leaves a lot out there we simply can't see.

Despite the exquisite resolution of the Hubble Space Telescope or the sensitivity of the twin Keck telescopes, today's powerful observatories can barely scratch the surface when probing this "shadow universe." We will never understand the architecture of the universe by studying starlight.

This calls for an innovative and radically new "dark matter telescope," called the Large-aperture Synoptic Survey Telescope (LSST). It won't look for dark matter particles — whatever they are — but it will map the distribution of dark matter across the heavens with speed and agility, making it 20 times more powerful than today's telescopes. The LSST will open an unprecedented cinematic new view of the heavens — a glorious wide-screen, three-dimensional "movie."

Veteran dark-matter sleuth Tony Tyson of Bell Laboratories/Lucent Technologies and large-mirror master Roger Angel of the University of Arizona are part of the team of astronomers and physicists proposing the project.

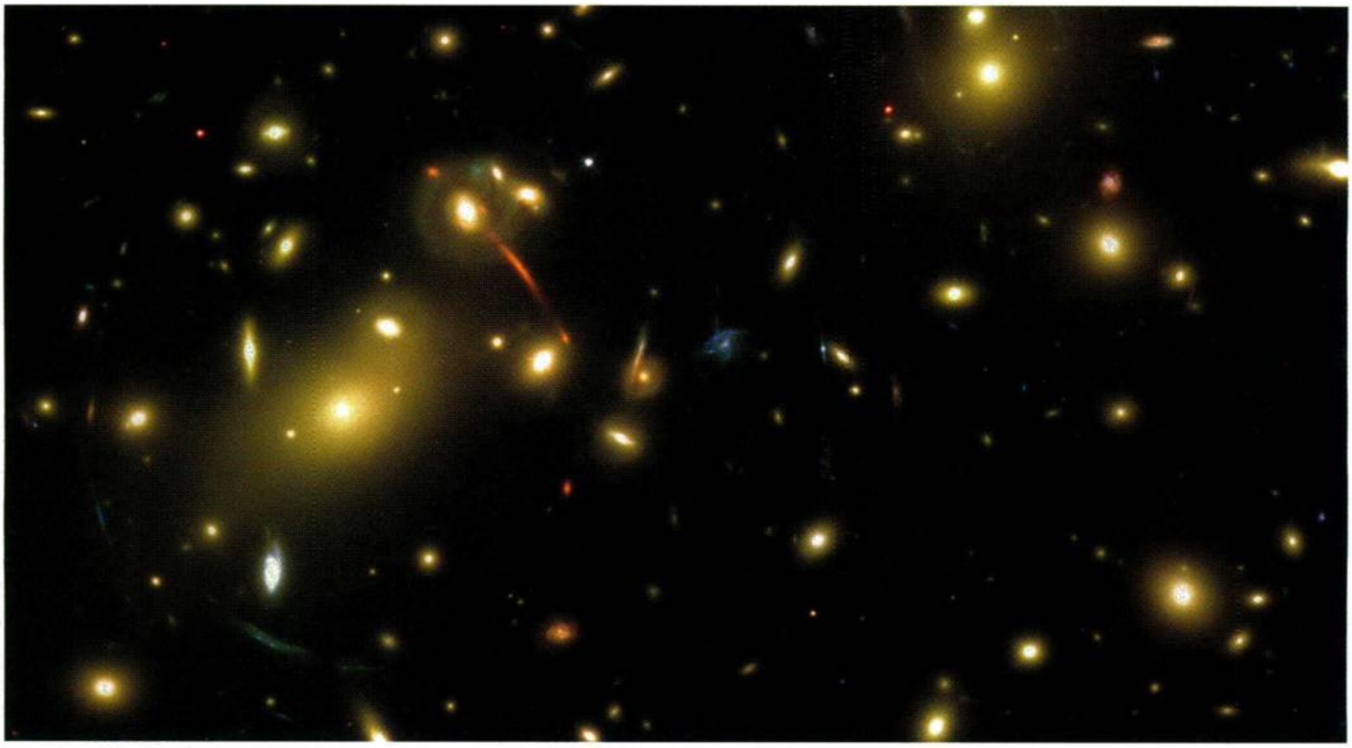
The LSST is a follow-on to the highly successful Sloan Digital Sky Survey. Sloan mapped one-quarter of the entire sky, determining the positions and brightnesses of more than 100 million celestial objects, and distances to more than a million galaxies and quasars. The LSST will also complement some of the proposed deep-sky cosmology missions such as the Supernova Acceleration Probe (SNAP).

The LSST will do what a few years ago would have been called Mission Impossible — map almost the entire sky every

The National Optical Astronomy Observatory's Deep Lens Survey shows incredible detail, but it will pale in comparison with what the Large-aperture Synoptic Survey Telescope has in store.

Deep Lens Survey and NOAO

RK
VERSE



Dark matter pervades the universe, as in the galaxy cluster Abell 2218, where its gravity distorts the light of more distant objects. The LSST will map the distribution of dark matter in the universe in unprecedented detail. NASA, ESA, Andrew Fruchter (STScI), and the ERO team (STScI + ST-ECF)

several nights down to 24th magnitude. That's so faint a threshold that the nightly inventory will number 200 million objects. "There will be about 30,000 galaxies and 3,000 stars per square degree of sky — not counting tens of thousands of asteroids," says Tyson. "We will repeat these exposures at least every 25 seconds through the night, tiling the sky with 7-square-degree patches."

Over time, a total of 14,000 square degrees will be covered with multiple exposures building an image down to 27th magnitude, which corresponds to 600,000 galaxies per square degree. The resulting image compilation and photometric catalogs will contain roughly ten billion objects: galaxies, stars, brown dwarfs, comets, asteroids, and energetic explosions in the early universe.

This will allow the LSST to directly image huge dark matter structures forming a ghostly cobweb across the universe. Acting as a movie camera, it will dramatically unveil the transient universe — one crackling, popping, and bubbling with titanic explosions and stellar flares.

"The LSST will do what a few years ago would have been called Mission Impossible."

Much closer to home, the LSST will also adroitly pick up the solar system's denizens of the night. It will chart the orbits of almost all asteroids and comets that pose a threat to Earth. The LSST will do a census of the Kuiper Belt, the solar system's last unexplored frontier.

The huge "discovery space" available to the LSST — only marginally accessible to today's telescopes — guarantees to make deep inroads into everything from probing the underpinning of the universe's origin and evolution to doing a complete inventory of our solar system. When opening a vast new frontier of discovery space, it's a good bet the telescope will deliver profound and unexpected discoveries that will reinforce the emerging view that the universe is far stranger than we dare imagine.

The telescope needed to accomplish such a Herculean task must be Herculean too. It requires an innovative optical design, a state-of-the-art "super-camera," and an extremely ambitious system to sort and archive the flood of data that in sheer volume will exceed everything collected by the present generation of telescopes.

Ten years ago such a revolutionary telescope could not have been conceived. Breakthroughs were needed in complex optical design, large detector mosaics, and large-volume data processing and handling.

The LSST's wide field of view means a short 10-meter focal length. The center of gravity is in the middle of the squat telescope so it can quickly pivot around a small turning radius inside a relatively small housing. To control the wide view, the telescope has three sets of mirrors. The large 8.4-meter primary will be a twin of the mirrors on the University of Arizona's Large Binocular Telescope.

Relative to other 8-meter-class telescopes, the LSST will be like a motor-driven handheld camera compared with a portrait-studio tripod-mounted bellows camera. To survey the sky, the telescope has to be agile enough to re-point by three degrees in merely five seconds.

The novel optical design will allow the LSST to go very deep and wide. The telescope will gaze at a whopping 4,000 square degrees of sky per night, 100 times the area of the bowl of the Big Dipper.

The LSST will be located at a prime ground-observing site with the best possible weather. A site in the mountains of Chile is under consideration. Ideally, a telescope in the Northern Hemisphere could combine with one in the Southern Hemisphere to cover the entire celestial sphere. Being on the ground rather than in space will keep construction costs to approximately $100 million, although seeing conditions will not be as optimal.

In the relative "blink-of-an-eye" 20-second exposure, the fast optics will plunge deep into the cosmos to capture faint stars and galaxies the size of our Milky Way halfway across the universe.

The tertiary mirror will feed starlight from its three-degree-wide field of view to a two-foot mosaic of dozens of optical detectors totaling two gigapixels. Starting a new exposure of a different part of the sky every 30 seconds, the LSST's camera will pour out image data at 500 megabytes per second. The torrent of imaging data from the LSST is unprecedented for any current optical telescope, but comparable to the data rates found in particle physics experiments.

Software must process the data stream in near real-time to automatically detect and classify both variable and moving objects, placing results in an archive that can be readily retrieved by the astronomical community.

Mapping the Shadow Universe

Despite today's vast array of magnificent ground- and space-based telescopes, it is humbling to realize we can't see the very substance that dominates the mass of the universe and controls the development of structure through its gravity. Amazingly, over billions of years, this dark matter established the underlying blueprint for assembling ordinary matter into galaxies, stars, planets, and life.

The gravitational effects of dark matter give the universe a "shower curtain" appearance caused by gravitational lensing. Albert Einstein first predicted this phenomenon when he theorized that gravity warps space. This means light can be deflected by gravity as it crosses space, like a golf ball rolling over uneven turf.

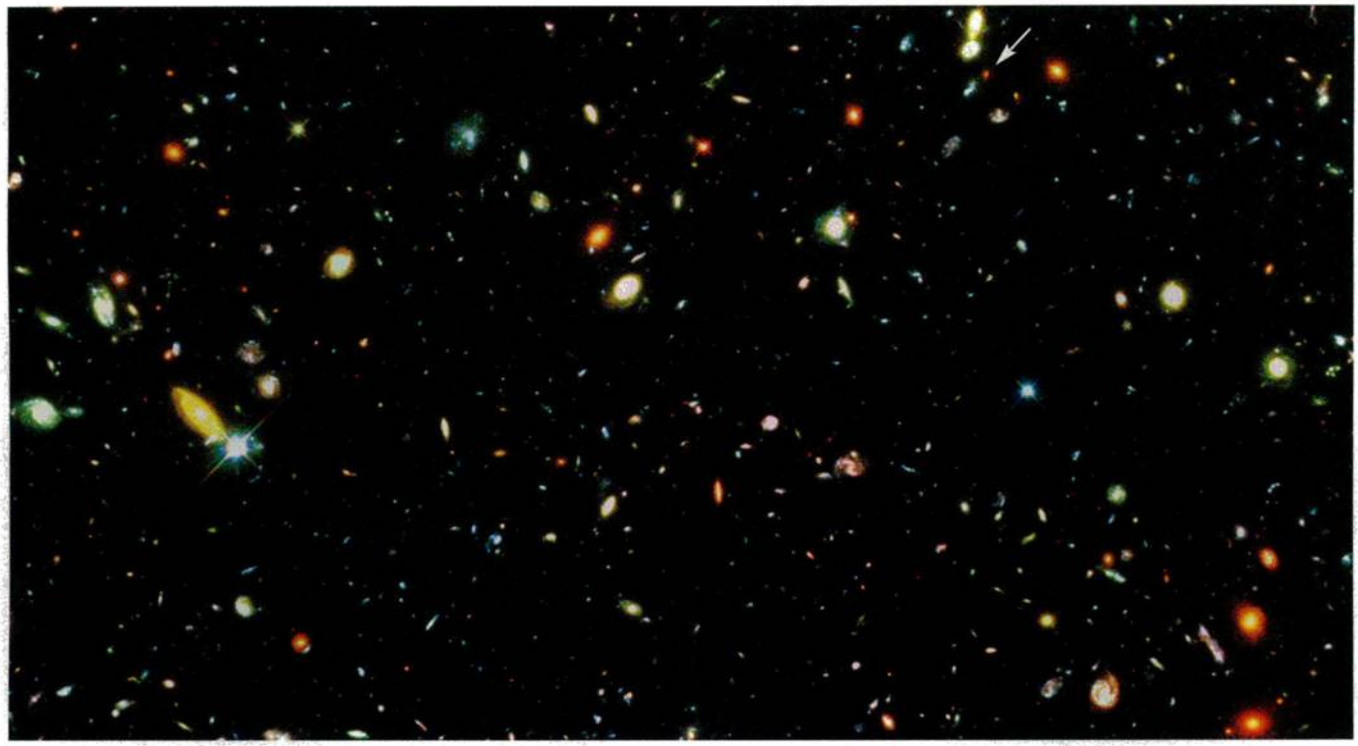
But you really don't understand how distorting a transparent shower curtain can be unless someone stands behind it and you see how much the person's appearance changes. Likewise, the light from billions of distant galaxies provides background wallpaper that is noticeably distorted by the foreground dark matter. The LSST will need optimum observing conditions to measure the "shear effect" on galaxies, a measure of how much their images are stretched by lensing.

The LSST will make a three-dimensional map of this dark matter by measuring distances to both the gravitationally lensed galaxies and the foreground clusters of mass loaded with the dark matter doing the lensing. Distances to the background galaxies will be measured based on their color. This technique, called photometric redshift, is used increasingly as a substitute to traditional spectroscopy that makes an unequivocal measurement of an object's cosmological redshift. But many distant targets are simply too faint for this tried-and-true technique to be used exclusively anymore.

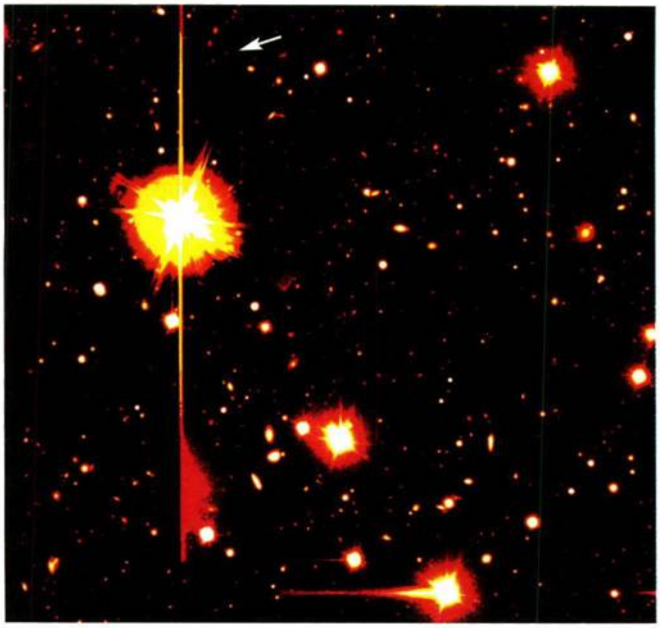
The LSST's mapping of dark matter will measure both the geometry of the universe and the growth rate of structure. The amount of distortion of the shapes of galaxies will help fine-tune the measure of the universe's balance of energy and matter. Dark energy damps the growth of structure, so the LSST will help determine the nature of the elusive dark energy that is now pushing the universe apart. The mapping will also identify galaxy clusters at great distances and will tell how quickly large-scale structure froze out of the dark matter web of the early universe. Gravitational lensing can also split images of distant quasars, and the frequency of this effect yields clues to how gravity curves space.

The LSST can play a role in probing the universe's underpinnings by searching for supernovae. Supernovae present a window into the distant past and offer the best way to measure how the universe's expansion has changed over time.

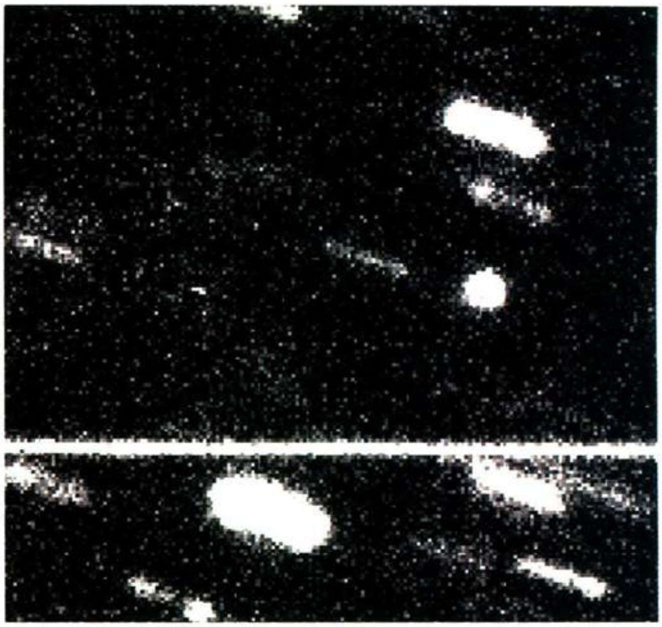
Hubble Space Telescope astronomers got lucky in 2000 with their chance discovery of a distant supernova. It was so far



The LSST will detect thousands of distant supernovae, like this one (arrow) in the Hubble Deep Field, helping to pin down the accelerating expansion rate of the universe. NASA and Adam Riess (STScI)



The LSST will excel at finding objects that flare up in the darkness of space, as did this gamma-ray burst (arrow) in January 2000. ESO



Astronomers have discovered about 500 Kuiper Belt objects, including the round smudge of 1996 TO66, seen here. The LSST should find at least 10,000 of these distant solar system objects. ESO

away that it yielded the long-awaited smoking-gun evidence that the universe once really was slowing down, but is now speeding up thanks to the repulsive pressure of dark energy.

If the universe were expanding at a steady rate, the light from distant supernovae would dim at a predictable rate depending on their distance from Earth. If the supernova light is brighter than predicted, the universe has been expanding slower than expected since the time the supernova exploded. If the light is fainter than predicted, the universe has been expanding faster than expected since the time the supernova exploded.

But many more remote supernovae must be found to help understand the nature of the dark energy that kicked the universe into high gear about 7 billion years ago. Ground-based surveys have not exceeded 300 supernovae per year. The LSST will complement the ambitious supernova survey planned by the proposed SNAP mission that is expected to find more than 1,000 supernovae at the critical epoch where the universe began to accelerate. SNAP will provide a deep "pencil-beam" view of the sky. The LSST's designers predict that its wide view and depth will trawl in 200,000 moderately distant supernovae per year.

Many theorists think the dark energy could percolate from the vacuum of space. The problem: the calculated value of this vacuum energy seems so absurdly powerful it would have blown apart the universe long ago. One way out is to have the vacuum energy vastly weaken over time. This leads to another idea called "quintessence" (for fifth essence) which proposes that there is a repulsive field embedded in space. In this scenario, as the universe expanded and cooled, quintessence won out over gravity and took control to push galaxies apart. Complementing the probe of dark energy through gravitational lensing, supernovae offer a different probe for determining the exact amount of push dark energy exerts — and the exact amount of resistance by dark matter.

"LSST will open a new window onto the early violent universe."

The LSST will also open a new window onto the early violent universe. In a universe long ago and far away, galaxies collided more frequently and stars were born in firestorms of creation triggered by collisions.

Astronomers started getting a hint of this violence in the 1970s when defense satellites picked up startling and puzzling gamma-ray bursts (GRBs). Unleashing 100 times the power of a supernova, these titanic bursts of gamma rays happen about once per day somewhere on the sky. Most reside billions of light-years away. They tell of a time when rapid star formation in the young universe led to bizarre "hypernovae" (the best explanation so far), which scientists believe are explosions of ultramassive stars that unleash a narrow beam of gamma rays like a blast from Darth Vader's Death Star.

If GRBs come from a narrow beam of energy pointed at Earth, the fainter ones should be beams not coming directly toward us. It's not clear how many GRBs are "off-axis," but only the LSST will be able to carve out this discovery space. With luck, the telescope's wide view will pick up fainter GRBs popping off like firecrackers. The telescope will capture their color and precise brightness, and track the fading light.

And GRBs form just the tip of the iceberg. A staggering variety of astronomical phenomena come and go like fireflies in the night. Collectively called transient events, they include outbursts from black holes powering active galaxies and quasars, variable stars and stellar flares, and microlensing events where a star momentarily brightens when a dim foreground object passes in front of it.

The LSST promises to yield new insights into our own galaxy by building a huge database of variable stars of many types, such as eclipsing binaries. There is a tantalizing opportunity to find extrasolar planets by capturing rare transiting events where a planet tracks across the face of its parent star.

The LSST will complete the survey of near-Earth objects larger than a football field across. Although typically much smaller than Eros, seen up close in this image from the NEAR-Shoemaker spacecraft, these objects pose a significant threat to Earth. NASA/JHUAPL

Astronomers also anticipate the LSST will turn up previously unknown objects and phenomena.

The LSST's wide field and sensitivity are not just for perusing the far universe. Much closer to home, at the frigid, far fringes of our solar system, perhaps billions of faint small bodies ply the dim highways of the Kuiper Belt. The discovery of the inhabitants of this vast icy "debris yard" beyond Neptune has climbed rapidly in the past few years. About 500 of these Kuiper Belt objects (KBOs) have been found so far, including a new population of binary KBOs that have raised questions about their evolution and dynamics.

The Kuiper Belt is one of the last big missing puzzle pieces to understanding the origin and evolution of our solar system and planetary systems around other stars. But astronomers have barely scratched the surface. The LSST will carry out a census of the Kuiper population by discovering more than 10,000 KBOs. With such a large statistical sample, astronomers will better understand one of the least-known regions of our solar system.

Extrasolar planetary systems yield startling evidence that giant planets have migrated, a process that presumably happened to some extent in our solar system. The orbits of the KBOs are the only fossil record of this activity. These orbits are imprints of how bodies were shuffled around during the demolition derby of the early solar system. Because many KBOs (including Pluto) are in resonance orbits with Neptune, they can be used to measure how Neptune ejected mass from the solar system.

Dust disks seen around other stars are no doubt replenished by collisions among Kuiper Belt-type objects. This seems common among young stars and offers fundamental clues to the birth of planetary systems. Ironically, less is known about the dust disk encircling our own solar system than those seen around other stars. And we know just as little about the small and dim objects orbiting beyond Neptune.

The LSST will be a tool for finding asteroids and comets zipping perilously close to Earth — collectively called Near-Earth Objects (NEOs). Astronomers estimate about 2,000 half-mile-wide asteroids cross our orbit. But the LSST's wide and deep view plus observation frequency will allow it to catalog thousands of NEOs as small as a football field. Most near-Earth comets have been hard to find because they glow dimly.

Though not in the "dinosaur-kill" class, objects 500 feet across should not be overlooked. A small NEO could flatten a city with the energy equivalent to a 1,000-megaton explosion. Within ten years the LSST could catalog 90 percent of asteroids down to 800 feet across.

Sky Patrol

The LSST will be operated differently from existing large telescopes. Rather than time being assigned to individuals or groups to carry out specific programs, the LSST will observe a pre-programmed series of fields, effectively imaging 10,000 degrees of sky every four nights.

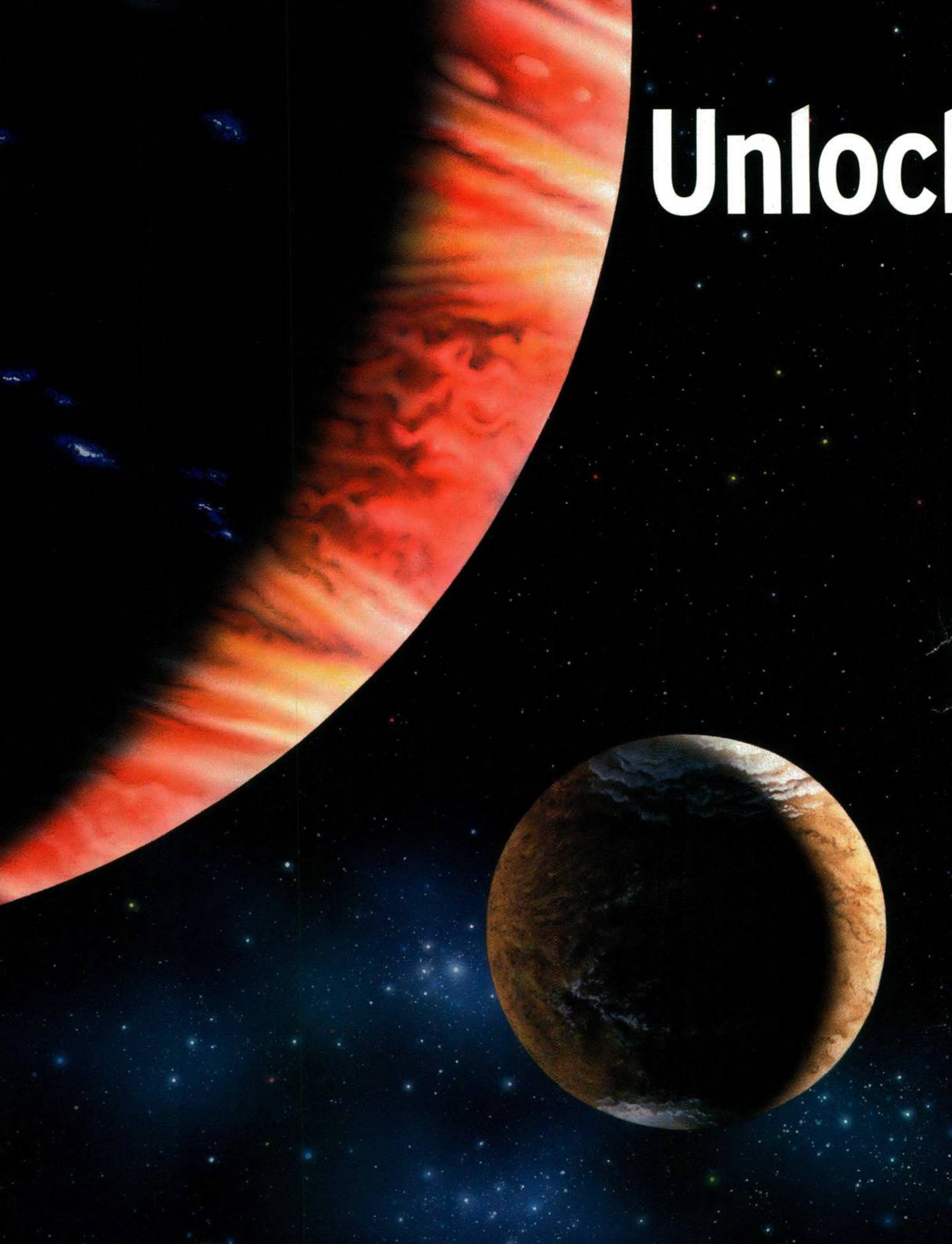
The whole-sky images, built up over time to faint levels, will provide critical support for follow-up research at a broad range of observatories. But the LSST's repeated imaging of each patch of sky means that science can also be done purely within the telescope's database, rather than the traditional follow-up mode using other telescopes.

It will be a challenge to come up with ways to sort through and provide rapid access to a true haystack of archived data — petabytes of imaging data and catalogs measured in terabytes. "This will present an interesting data mining challenge," says Tyson. This huge archive will be the biggest data mine feeding into the Virtual Observatory, an ambitious plan to allow astronomers to simultaneously analyze data from several of the dozens of astronomical databases available today.

The LSST will be used for projects undreamed of, undertaken with the legacy of a truly enormous database as well as with new observations. "We are driven to build the LSST facility by what we know today it can tell us about our universe," says Tyson. "But it is what we cannot predict that may ultimately be the biggest reward." ■

Ray Villard is public information officer at the Space Telescope Science Institute in Baltimore, Maryland.

Unlock



king New Worlds

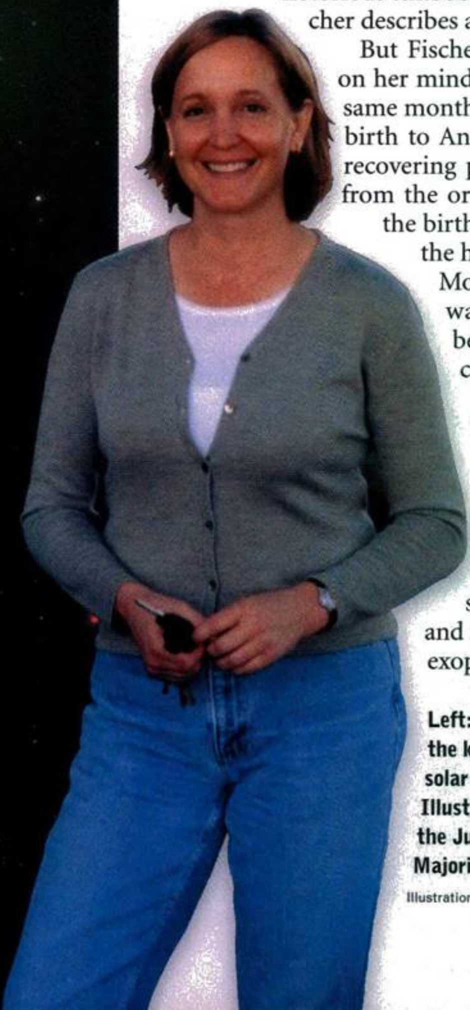
How one astronomer stays on the cutting edge in the race to discover a planetary system like our own.

By Robert Naeye

In April 1989, a San Francisco State University physics graduate student named Debra Fischer was taking an advanced classical electrodynamics course. Her professor, Susan Lea, demanded that her students take courses just as rigorous as those completed by their counterparts at top-rank universities such as Harvard and Cambridge. To achieve this end, Lea assigned a notorious textbook by J. D. Jackson, one that Fischer describes as "dreadfully difficult."

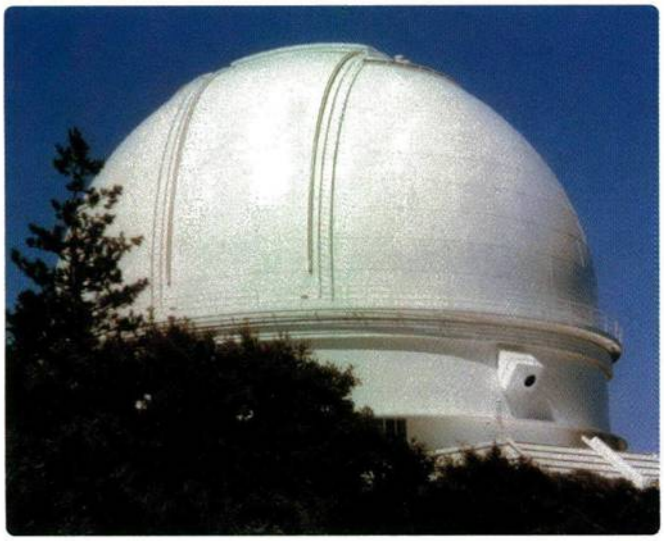
But Fischer had more than just physics on her mind. On a Saturday morning that same month, she went into labor and gave birth to Anna, her second daughter. Still recovering physically and psychologically from the ordeal of labor, and elated over the birth of a healthy baby, Fischer left the hospital early to attend class on Monday morning. "I could barely walk. But I didn't want to fall behind and have to re-take the course," she recalls.

Now, 13 years later, Fischer brings that same level of determination to one of the most exciting fields in science — the search for planets outside the solar system. Ten years ago, astronomers could only speculate about the frequency and nature of extrasolar planets (or exoplanets, as they're now called).



Left: Astronomer Debra Fischer holds the keys to discovering life beyond our solar system.
Illustration: This artist's depiction shows the Jupiter-like exoplanet 47 Ursae Majoris b and a hypothetical moon.

Illustration by Lynette Cook / All photos by Robert Naeye



The 3-meter Shane Telescope, which has been instrumental in the search for extrasolar planets, is housed in this dome at Lick Observatory, near San Jose, California.

But thanks to the efforts of astronomers like Fischer, we now know that planets are common throughout the galaxy. Astronomers have found more than 10 times as many planets outside the solar system as within. And as more teams and technologies join the search, the pace of discovery will accelerate. A decade from now, astronomers will probably know of many hundreds of exoplanets, including planets that remind us of Earth. As Fischer says, "The question is no longer how many stars have planets, it's which stars don't have planets."

To reveal the science behind the headlines, I spent two nights at the telescope with Fischer during an observing run at Lick Observatory on Mt. Hamilton, near San Jose, California, and I later paid a visit to her University of California–Berkeley office. What the public doesn't see is the fact that planet hunters spend most of their time getting down and dirty in the trenches — sifting through massive catalogs to decide which stars to observe, worrying about the slightest technical glitches in their equipment, and squeezing every last second of observing out of a precious night at the telescope. But out of this seemingly mundane list of procedures will come some of the most profound scientific discoveries of all time — discoveries that bear directly on the question of whether planets similar to Earth exist, and whether we're alone in the universe.

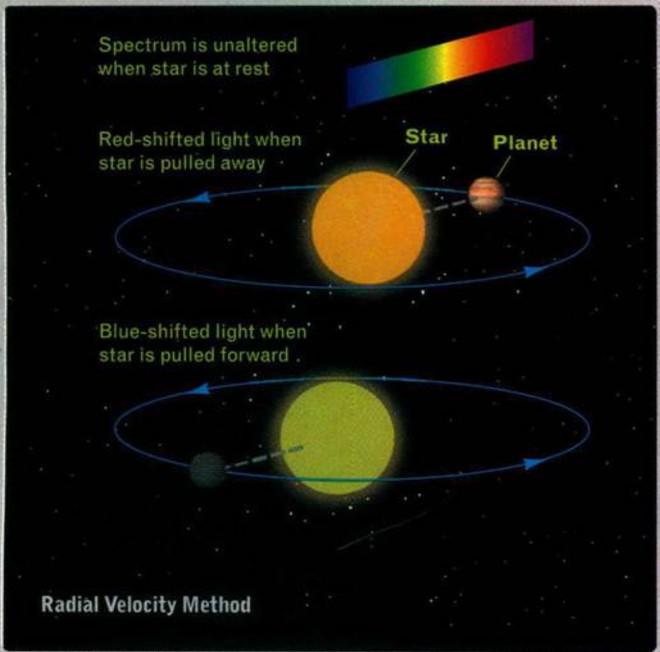
In 1997 Fischer joined the team that is leading the charge in the great exoplanet race. The pace-setting collaboration, led by UC–Berkeley colleague Geoff Marcy, and Paul Butler of the Carnegie Institution of Washington, has racked up more than 70 exoplanets. But apart from this sheer number of planets, the team has repeatedly grabbed headlines for being the first to discover new categories of objects, including the first exoplanet with a highly eccentric orbit, the first exoplanet with an earth-like orbit, the first planet to transit its host star, and the first exoplanet with a mass and orbit similar to Jupiter's.

While Marcy and Butler search for planets with the 10-meter Keck Telescopes on Mauna Kea in Hawaii, Fischer pursues planets with 0.6- and 3-meter telescopes at Lick. With these telescopes, Fischer added to the Marcy/Butler team's list of important "firsts" in 1999 when she discovered the second and third planets orbiting Upsilon Andromedae — the first known planetary system around another solar-type star. (Penn State astronomer Alex Wolszczan discovered the first exoplanet system in 1991 when he found three planets orbiting the pulsar PSR B1257+12.)

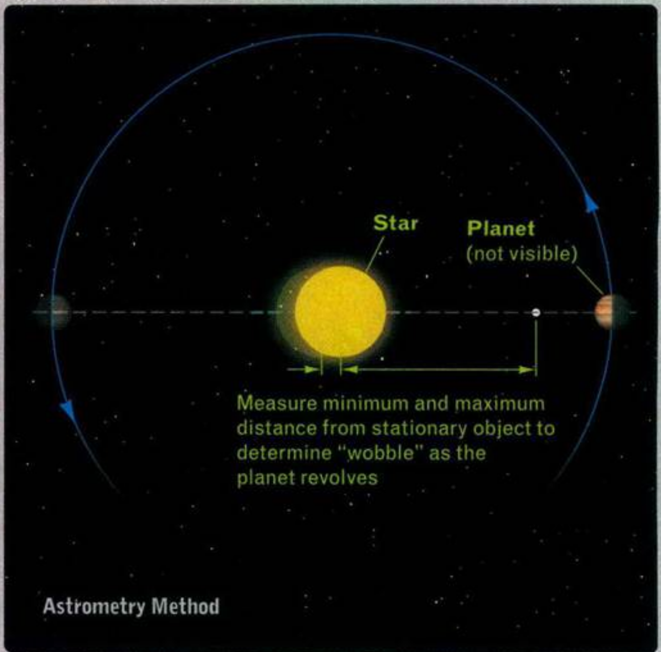
Precision, Precision, Precision

What contemporary planet hunting is really all about is patience, perseverance, and attention to detail. Planet-hunters

Presented below are the only four known ways to detect extrasolar planets to date.


Spectrum is unaltered when star is at rest
Red-shifted light when star is pulled away
Star
Planet
Blue-shifted light when star is pulled forward

Radial Velocity Method


Star
Planet (not visible)
Measure minimum and maximum distance from stationary object to determine "wobble" as the planet revolves

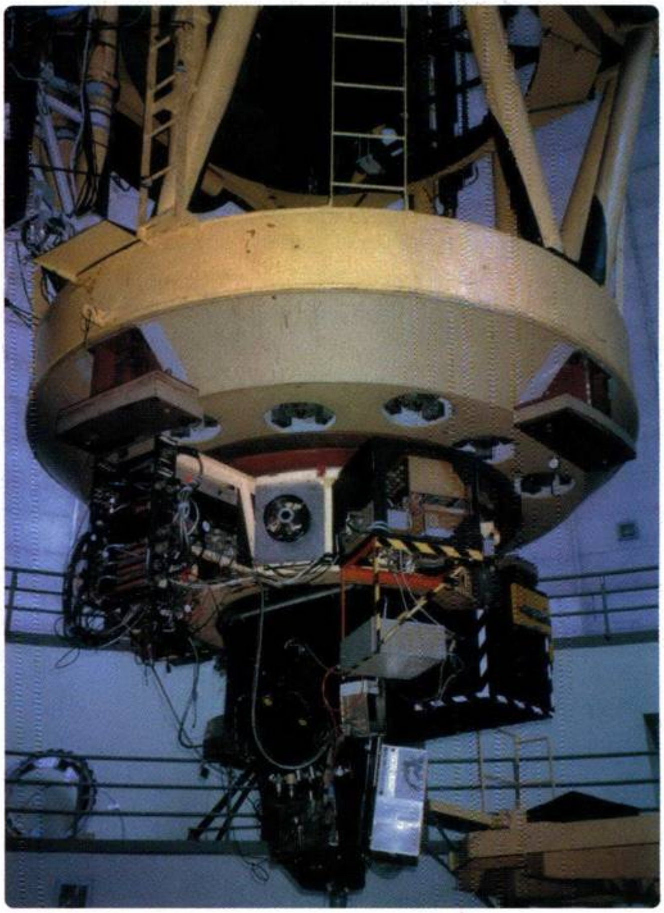
Astrometry Method

like Fischer bag their quarry indirectly. They must gather enough starlight for a good spectrum, disperse the starlight into its constituent rainbow of colors, identify characteristic dark spectral lines caused by light-absorbing elements in a star's upper atmospheres, and employ computer programs to tease out incredibly tiny shifts in those spectral lines.

With this "radial velocity" method for detecting planets, spectral line shifts are an indicator that the star is being yanked to and fro by the gravity of one or more orbiting planets. For example, during Jupiter's 12-year orbit, the sun is tugged toward and away from Earth at a speed (or radial velocity) of 12 meters per second. Although this is the speed of a world-class sprinter, it's a snail's pace by cosmic standards, translating to measly shifts in the sun's spectrum about 1/1,000th the width of a human hair.

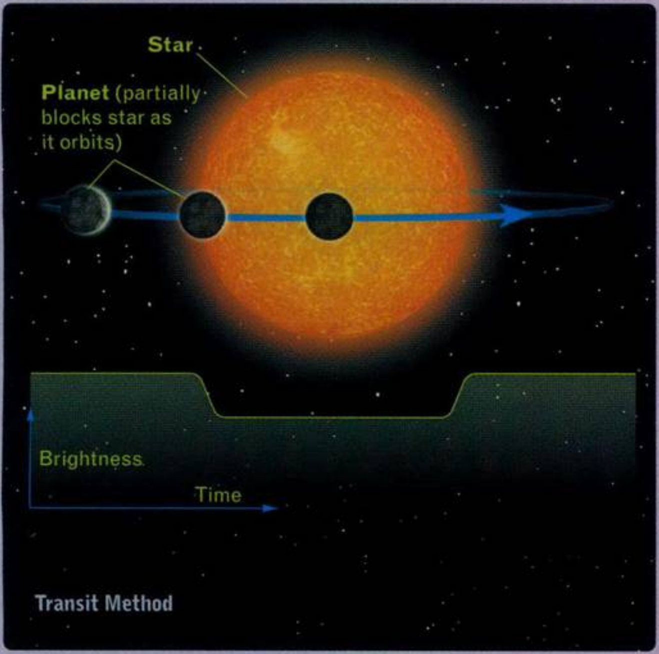
A decade ago, astronomers could only dream of achieving this level of precision. But armed with sophisticated new spectrometers and CCDs, the Marcy/Butler/Fischer team can now detect stellar radial velocities as slow as 3 meters per second, the speed of a brisk walk. This has enabled the team to find close-orbiting planets with masses lower than Saturn, and Jupiter-mass planets orbiting farther out.

But this extraordinary precision is no longer good enough. "We want to break new ground," explains Fischer. The 100 or so exoplanets found so far tell astronomers that planets are commonplace. But how many planetary systems are like ours, whose Jupiter-class planets follow distant, circular orbits that leave plenty of space for terrestrial planets in the sun's habitable zone? Only a handful of the planets found so far even remotely resemble their solar system counterparts (see "A League of Their Own," page 52). To find new types of planets, particularly those with long orbital periods, and those with just a few times the mass of Earth, Fischer's team needs to push its equipment to the limit, achieving a precision of two meters per second and perhaps ultimately even one meter per second.

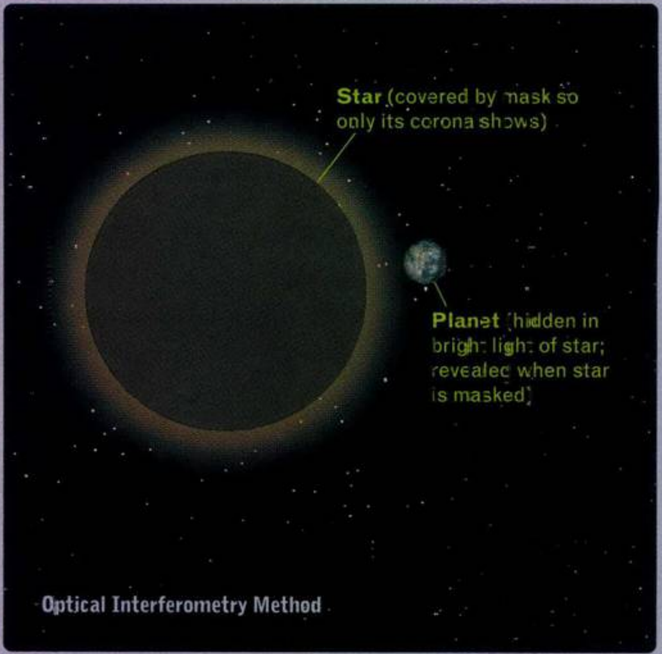


With the help of the Shane Telescope, pictured here, Fischer discovered the first known planetary system around another solar-type star. She spends 24 to 28 nights per year perusing the skies with this scope.

Visit Astronomy.com and go to the magazine page to view animated versions of these diagrams.

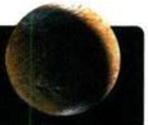


Transit Method


Star (covered by mask so only its corona shows)
Planet (hidden in bright light of star; revealed when star is masked)

Optical Interferometry Method

Astronomy: Rick Johnson



A league of their own

Very few of the exoplanets discovered in the last 11 years resemble their solar system counterparts. Most are much more massive than Earth and have wide-ranging orbital periods and eccentricities. In some cases, a star's protoplanetary disk gravitationally perturbs its fledgling planets, dragging them inward and consuming them while leaving behind a massive planet orbiting perilously close to the star's surface (a so-called hot Jupiter). In other systems, two or more massive planets may form in nearby orbits, along with smaller planets in orbits of their own. Once the more massive planets begin to gravitationally interact, their orbits become more elliptical. And amid the gravitational maelstrom, these wandering brutes may slingshot Earth-sized planets into the frigid depths of interstellar space, while at the same time leaving behind one or two survivors in highly eccentric orbits.

Sifting Gold from the Gravel

The first step in finding exoplanets is to identify the right kinds of stars to observe. Fischer currently has 400 stars (what she affectionately calls "her babies") on her observing program. Marcy and Butler started observing 100 of these stars at Lick a decade ago, when their planet search was in its infancy. They have since moved their observing program to the Keck Observatory on Mauna Kea in Hawaii. So Fischer keeps track of those original 100 stars, and has added another 300 to the list.

"Target selection is fun, but a lot of work goes into it," says Fischer. She has to pore over star catalogs and, in consultation with other astronomers, identify the relatively few stars that are bright enough to be observed with the Lick 0.6- and 3-meter telescopes, but which also exhibit numerous and narrow spectral lines. Stars with a close binary companion won't work, because radial velocity shifts induced by the nearby star totally swamp the tiny motions induced by planets. Fischer also tosses out stars with active atmospheres, because the churning motion of atmospheric gases can closely mimic Doppler shifts caused by planets. Finally she discards rapidly rotating stars because the fast spinning smears out spectral lines, leading to low radial velocity precision.

It turns out that the stars that work best for radial velocity planet searches tend to be stars similar to the sun, and are therefore also most likely to support life as we know it.

Tools of the Trade

The Keck Observatory awards Marcy and Butler about 10 to 20 nights per year on one of its twin 10-meter telescopes. In contrast, Fischer uses the Lick 0.6-meter Coudé Auxiliary Telescope (CAT) 60 to 80 nights per year, and she is awarded 24 to 28 nights per year on Lick's 3-meter Shane Telescope, which is the king of Mt. Hamilton.

At the start of a typical three-night Shane Telescope run, Fischer will arrive in the early afternoon, often with a graduate student in tow. She carefully inspects all the gadgets and gizmos to make sure every piece of apparatus is working perfectly. "We have to make sure that everything is so constant in our setup that nothing else introduces a tiny shift in a star's spectrum," she explains.

"The devil is in the details," says Fischer. "There are 100 things that can go wrong. If you get 99 right, that's not good enough." During a CAT observing night last year, for example, a student forgot to heat up the iodine cell. (Gaseous iodine superimposes a reference series of stationary spectral lines onto the star's spectrum, against which Fischer compares the star's shifting spectral lines.) In the cold winter air, the iodine remained as liquid droplets clinging to the side of the iodine cell. Without any iodine in the spectra, it was impossible to measure velocities for the five stars observed that night.

But Fischer is also quick to acknowledge that her students are vital cogs in the planet-hunting machine. "Students are great to work with," she says. "One grad student made improvements in our data reduction software. These kinds of students give a lot back."

Fun With Wobbles

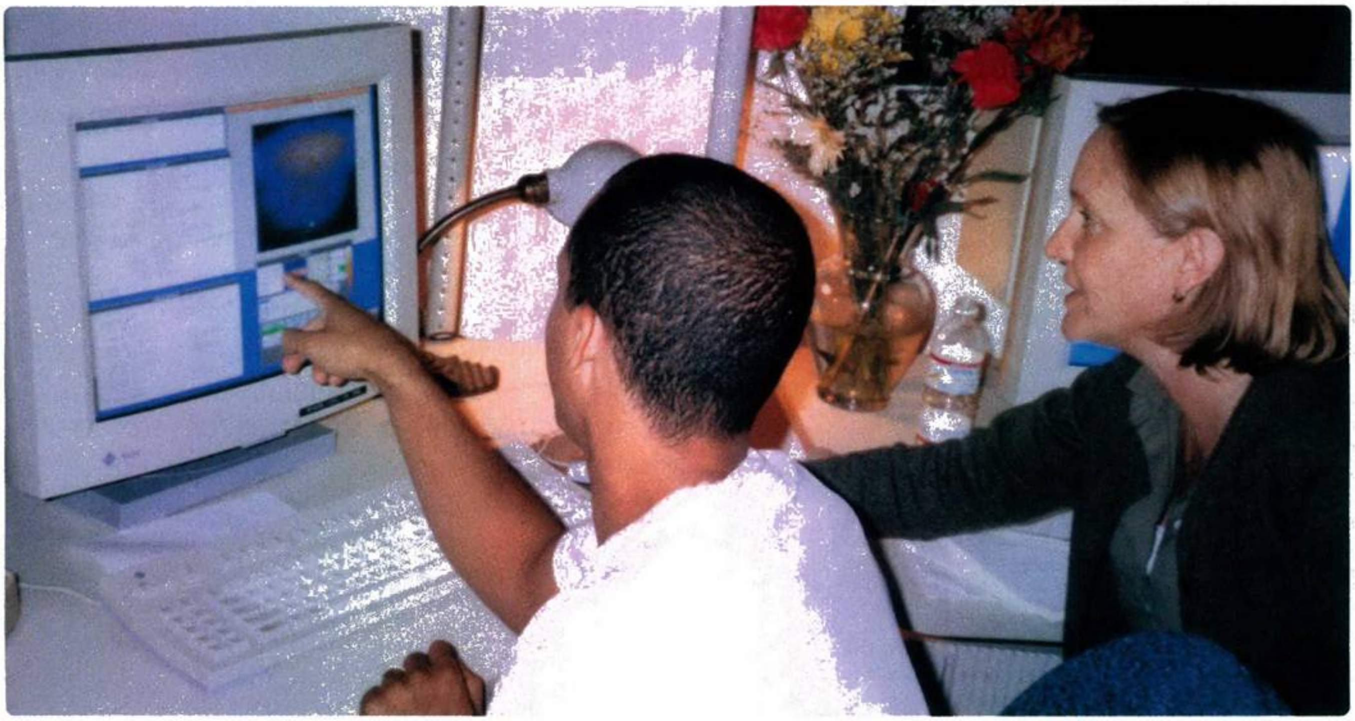
For the first night of her observing run, Fischer has drawn up a list of 40 target stars, and arranged them in order to help minimize the time it takes the telescope to slew from one target to the next. Of the 250 or so stars available on a given night, Fischer gives priority to those already known to possess planets with the hope of adding to the growing list of stars with multiple planets. "We think more than half the stars with one giant planet have at least one more detectable planet," she says.

When Fischer adds a new star to her target list, she'll observe it three nights in a row to see if it has a particular type of exoplanet known as a "hot Jupiter," whose incredibly short orbital periods (10 days or less) make them easy pickings for the radial velocity method. In hindsight, it's no surprise that the first exoplanet found around a solar-type star was a hot Jupiter orbiting 51 Pegasi, discovered in 1995 by Swiss astronomers Michel Mayor and Didier Queloz.

Fischer also assigns priority to stars that appear to have Jupiter-mass planets in long-period orbits. Because these planets are far away from their host stars, their tug is subtle and easy to miss. In addition, these planets take a dozen or more years to complete a single orbit. Fischer observes these stars frequently (what she calls "high cadence") to make absolutely sure that any changes she detects in a star's velocity fit a characteristic pattern induced by an orbiting planet, and are not the result of stellar activity or random noise in the data. These are the systems of greatest interest to Fischer because low-mass terrestrial planets could be hiding closer in to the star. "You have to pound away at these low-amplitude systems because they're really hard to see," she says.

After worrying about weather, making sure every piece of equipment is working perfectly, and staying up all night at the telescope, comes the fun part: analyzing the data. For the stars that exhibit velocity variations, Fischer tries fitting the data with theoretical models based on the laws of planetary motion devised by Johannes Kepler in the early 1600s. When the team discovers a good fit to the data, it has a prediction in hand. If subsequent velocities continue to follow the predicted theoretical curve, then the detection is secure.

On a few occasions, where a massive planet is orbiting close to a star, the stellar velocities display simple periodic motions that literally shout, "Here's a planet!" But most planets orbit farther out, so their signatures are not immediately obvious. Fischer uses a computer program (a Fourier analysis) called a periodogram to tease out the signals for these planets with long orbital periods. "The most fun part of my job is constructing the fit, and then once you have a fit, going back to the



Fischer and University of California-Berkeley graduate student John Johnson analyze data in the control room of the Shane Telescope.

observatory to see if you're right," she says. Once she thinks she has found a planet, she'll observe the star to see if the velocity trends continue to hold up. Only then will she tell her colleagues about the discovery.

Tough Company

Historically, the field of planet hunting has suffered a notorious track record of planets being announced and later retracted. Yet the Marcy/Butler team has yet to retract a single planet announcement. The team has a strict policy of observing a planet's entire orbital period before announcing a discovery. "There's no tougher referee panel than the people in our group," says Fischer.

Always in the back of her mind is competition from other planet-hunting groups, particularly the Swiss. While the competition is friendly on the surface, there's a complex relationship underpinning the search efforts. "There have been a few things that have upped the ante," says Fischer. "They feel we've scooped them, we feel they've scooped us. The competition keeps us alert and moving."

On the positive side, this healthy competition fosters maximum effort. "I want to get every planet I can, not so much for me, but for my team. I want to do well for them. The competition is now fueling a race by both groups to achieve velocity precision below 3 meters per second," says Fischer.

Fischer exudes great confidence in her team's relentless pursuit of planets, but that confidence never crosses over the line into arrogance. "All I care about is finding out the truth," she stresses. Truth and respect for the scientific process are the guiding principles that govern every aspect of her work.

It's All About Life

Despite the team's worldwide celebrity, Fischer and company are hardly content to rest on their laurels. "The big question is whether long-period planets have circular or elliptical orbits," says Fischer. "The problem is that these stars have low amplitudes, so we need to observe these stars on a regular basis." To achieve "high cadence" on these promising stars, the Marcy/Butler team has recently secured funding for a dedicated 2-meter telescope at Lick. This telescope, which has been dubbed Automated Planet Finder, will be devoted almost entirely to the planet search effort.

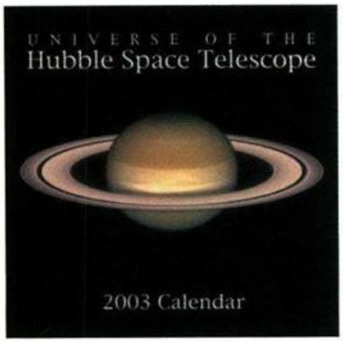
New techniques for finding planets are also coming online. Within a few years, astronomers may unveil direct infrared images of hot, newborn planets. Later this decade, NASA's ambitious Kepler mission should find dozens of Earth-sized planets (and possibly hundreds of Jupiter-sized planets) by watching them transit their host stars. Some astronomers predict that the Doppler method will soon be as outdated as computer punch cards. But Fischer doesn't buy that argument. "The radial velocity method is not ending anytime soon. We have over a decade left of good work," she asserts.

By pointing out which stars have Jupiter-sized planets in distant, circular orbits, the radial velocity teams are conducting a reconnaissance to find out which planetary systems have the highest potential for supporting life. Later space missions such as the Space Interferometry Mission and Terrestrial Planet Finder will rely heavily on the radial velocity planets to know which systems to search.

The exoplanets found to date, and in particular, the exoplanetary systems, are telling theorists a great deal about how planetary systems form and evolve. While these issues are fascinating in their own right, Fischer is quick to concede that the search for planets really boils down to a search for life. "This is a long, tedious process," she says. "We're hammering out the details. We know that life forms easily. But we need the petri dishes — the planets. If planets form easily, then there are lots of petri dishes." ■

Robert Naeye is editor of Mercury, *a bimonthly magazine published by the Astronomical Society of the Pacific. He is the 2002 recipient of the David N. Schramm Award for High Energy Astrophysics Science Journalism.*

Introducing Astrographics' Skywatching Guide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2003 Calendar

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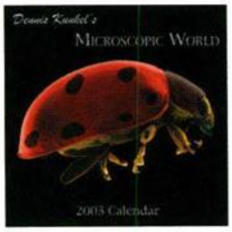
Dennis Kunkel's
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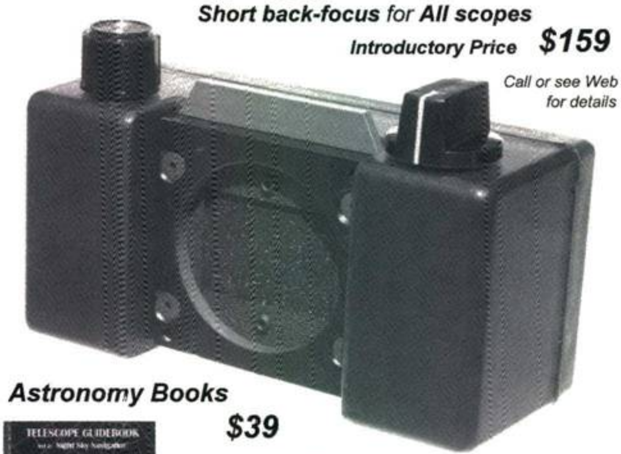

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sky Show

November 2002

The Leonids return.

by Martin Ratcliffe and Alister Ling

▶ The Leonid meteor storm, the most anticipated astronomical event of the year, occurs around 5:30 A.M. EST (2:30 A.M. PST) on November 19 for the Americas. Hundreds to thousands of shooting stars per hour may streak across our skies when streams of dust from an old comet burn up in Earth's atmosphere.

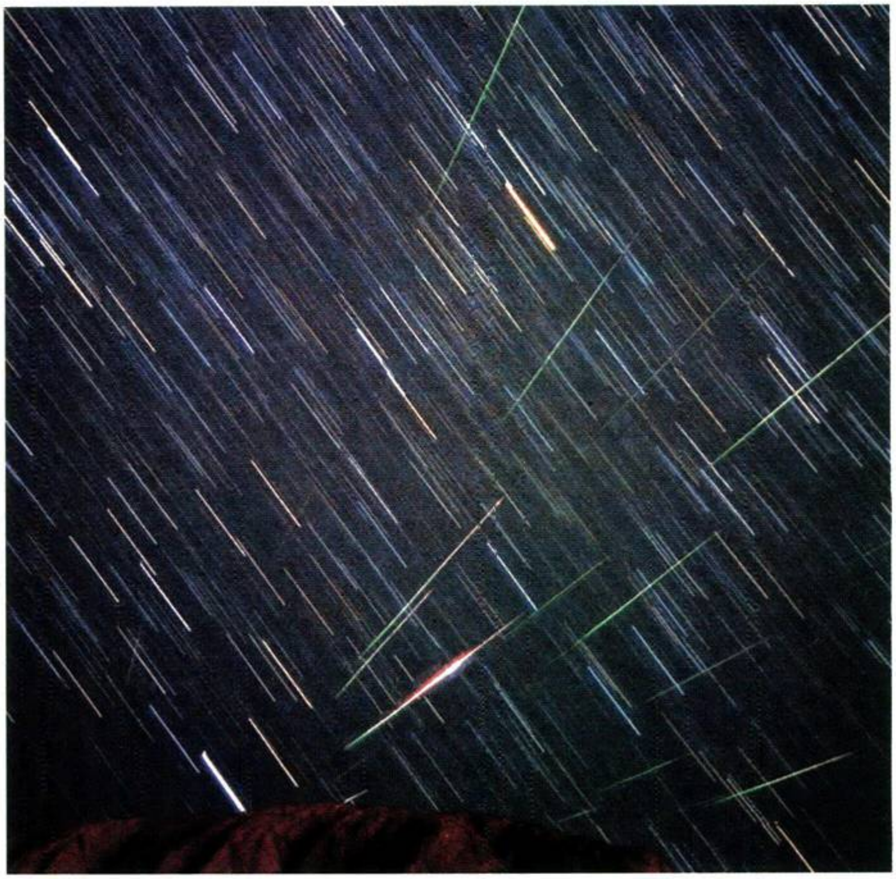
Don't worry about the moon. Its glare will overwhelm the faint meteors, but if the optimistic predictions come true, you will see more meteors under moonlight this year than during last year's moon-free deluge of swift shooting stars. If you can afford only a few minutes to step outside, be sure to do it at peak time. Otherwise, prepare to go out with at least two hours on either side of peak to make sure you don't miss these celestial fireworks altogether.

Considering that our next chance to catch a Leonids "storm" is in 30 years, and it's not predicted to be as great a show, this year's event may well be worth driving hours just to find a clear patch of sky.

In a complete anti-climax, there is a penumbral eclipse of the moon on the evening of November 19. The top limb will appear more yellow than usual as sunlight passing through Earth's atmosphere has its blue scattered away.

If it's fairly cloudy on Leonid night, you can take some consolation in observing the most beautiful telescopic sight in the sky: Saturn. The yellowish orb with its magnificent ring system rises in mid-evening. The nicest views come after midnight when it's higher in the sky, above the thick part of the atmosphere down near the horizon. The rings — open just about as wide as possible —are a show-stopping sight. Also, keep an eye out for Saturn's brightest moons.

The solar system's biggest planet, Jupiter, rises at midnight, and hits its peak as dawn begins to break. If you can leave your scope out all night without it drowning in dew or harvesting a hoary frost, you'll probably be rewarded with a wealth of cloud-top swirls in the planet's famously dynamic atmosphere.



2001 Leonids streak over the monolithic Ayer's Rock in central Australia. Russo Massimo

Join the ranks of hundreds of observers by finding Jupiter during the day with the unaided eye. After sunrise on Tuesday morning November 26, take a close look at the moon. Look south by 4° (eight apparent moonwidths), and see if you can pick out the pinprick of light that is Jupiter. Some people find rotated polarizing glasses help increase the contrast. You can always use binoculars to confirm your sighting, though.

Brilliant Venus vaults into the morning sky during the second week of November. Telescopically, the "morning star" displays a large thin crescent that slowly begins to fill out into a glowing golden orb over the following days as it races upward to catch up to Mars.

The crescent moon joins Venus and Mars in a nice triangle on the morning of December 1. Mars will be faint, but all three objects will fit in the field of most 10x50 binoculars. Earlier, on the afternoon of October 31, expert observers can try for our sister planet Venus when it's 6° south of the sun. (Make sure that you don't allow sunlight to accidentally enter the telescope). This so-called "inferior conjunction" provides a prime opportunity to observe the horns of the crescent shape reach around and join together.

2002 November

2 The moon passes 4° north of Mars, 1 P.M. EST

3 The moon passes 0.6° south of Juno, 7 A.M. EST
The moon is at perigee (222,546 miles from Earth), 7:46 P.M. EST

4 New moon is at 3:34 P.M. EST

10 The moon passes 5° south of Neptune, 5 P.M. EST

11 First quarter moon is at 3:52 P.M. EST
The moon passes 5° south of Uranus, midnight EST

13 Mercury is in superior conjunction, midnight EST

16 The moon is at apogee (252,150 miles from Earth), 6:30 A.M. EST

18 Asteroid Nysa is at opposition, 1 A.M. EST
Venus is stationary, 11 P.M. EST

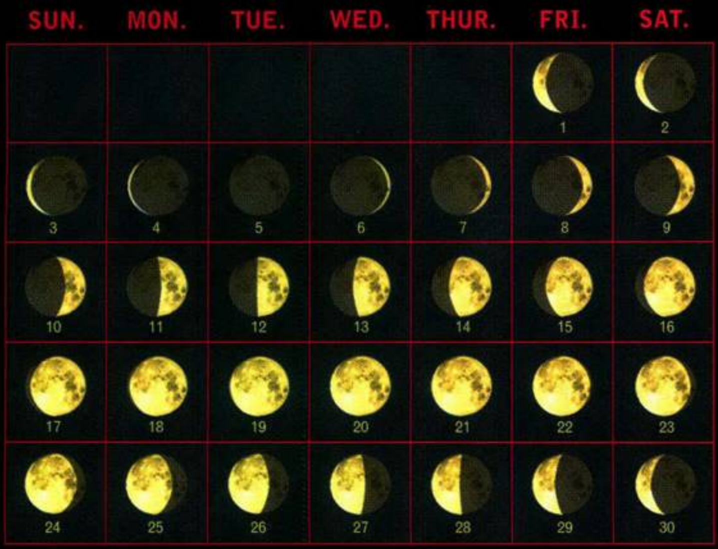
19 Leonid meteor shower peaks (page 64)
Full moon is at 8:34 P.M. EST; penumbral lunar eclipse
Mars passes 3° north of Spica, midnight EST

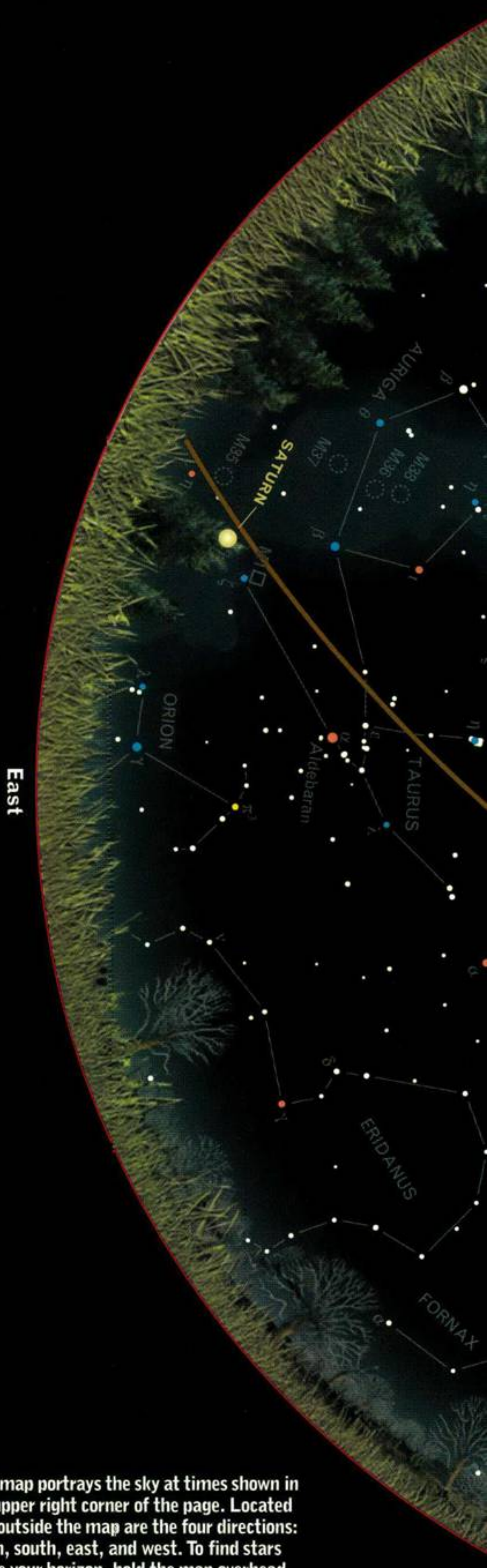
22 The moon passes 3° north of Saturn, 7 A.M. EST

26 The moon passes 4° north of Jupiter, 2 A.M. EST

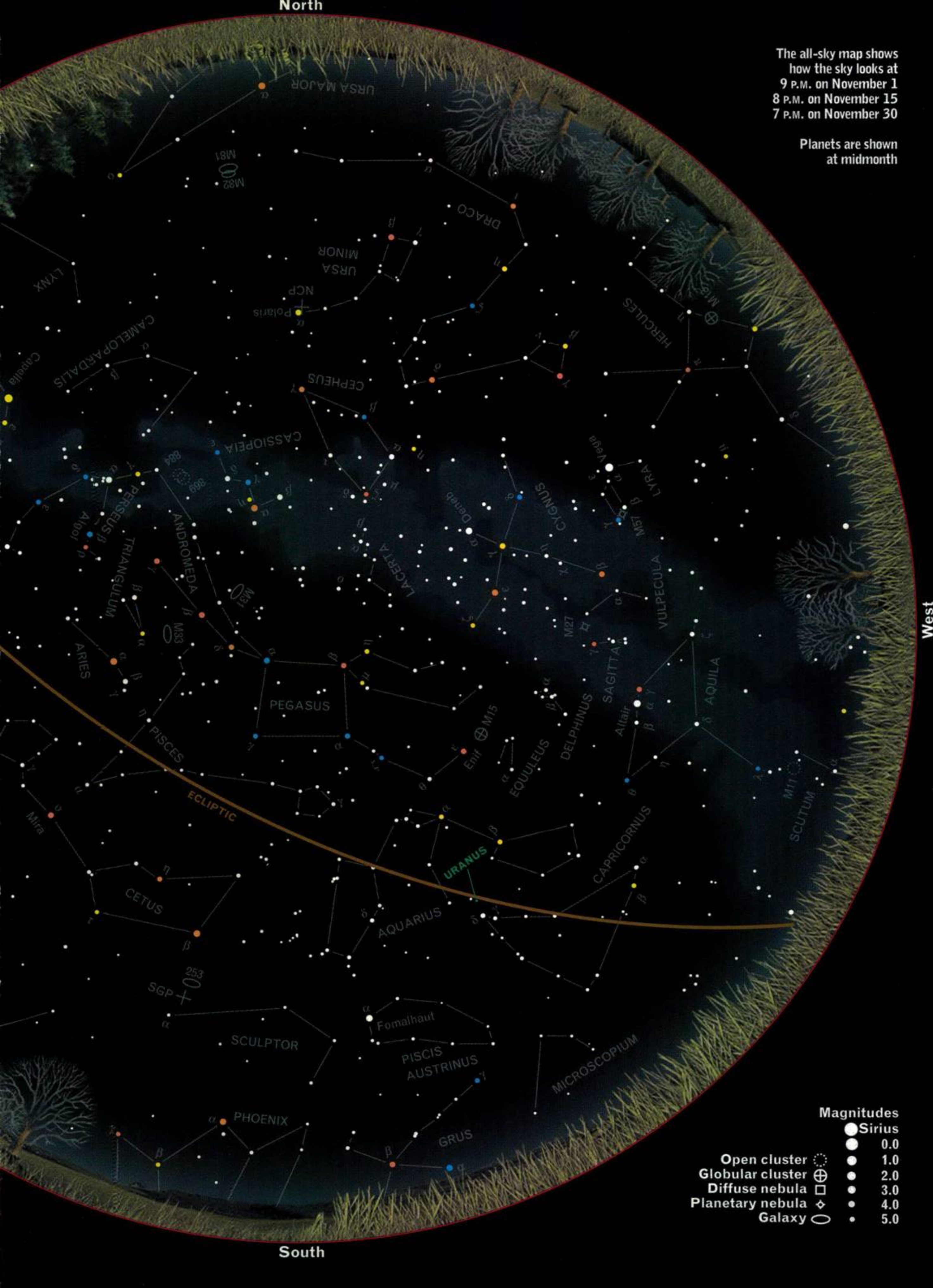
27 Last quarter moon is at 10:46 A.M. EST

28 The moon passes 0.04° south of Vesta, 10 P.M. EST





This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

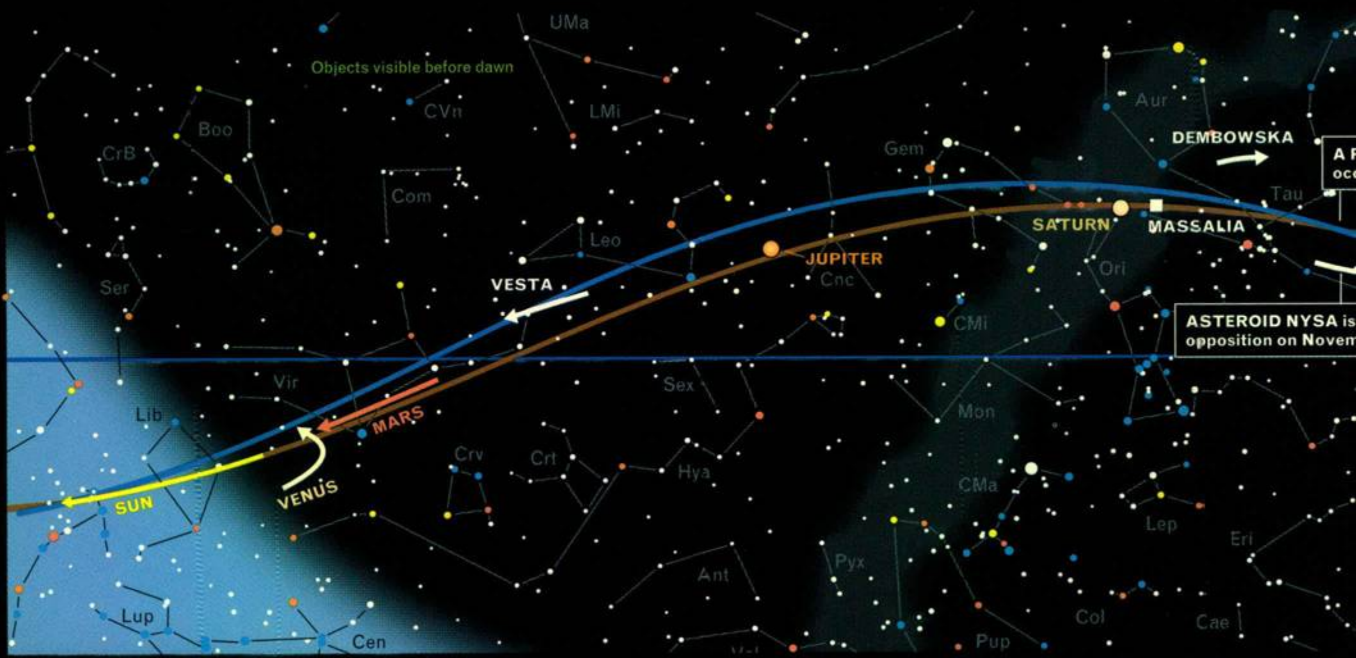

North
URSA MAJOR
M81
M82
DRACO
URSA MINOR
NCP
Polaris
LYNX
CAMELOPARDALIS
Capella
HERCULES
M13
CEPHEUS
CASSIOPEIA
884
869
PERSEUS
Algol
Vega
LYRA
CYGNUS
Deneb
M57
TRIANGULUM
ANDROMEDA
M31
LACERTA
VULPECULA
M27
M33
ARIES
SAGITTA
AQUILA
PEGASUS
DELPHINUS
Altair
West
M15
PISCES
Enif
EQUULEUS
M11
SCUTUM
Mira
ECLIPTIC
CAPRICORNUS
URANUS
CETUS
AQUARIUS
SGP
253
SCULPTOR
Fomalhaut
PISCIS AUSTRINUS
MICROSCOPIUM
PHOENIX
GRUS
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
9 P.M. on November 1
8 P.M. on November 15
7 P.M. on November 30

Planets are shown
at midmonth

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objec


UMa
Objects visible before dawn
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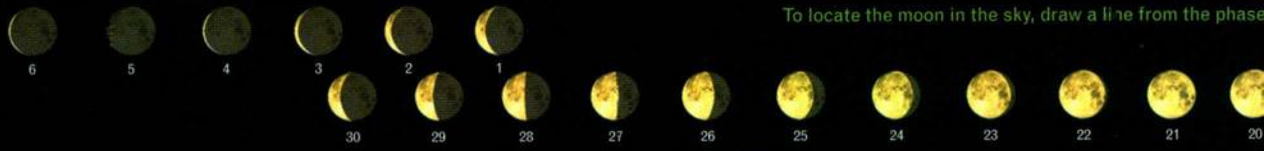
CrB
Com
Leo
Ser
Gem
Aur
DEMBOWSKA
A F
occ
Tau
SATURN
MASSALIA
JUPITER
Cnc
Ori
VESTA
CMi
ASTEROID NYSA is
opposition on Novem
Sex
Vir
Lib
MARS
Mon
Crv
Crt
Hya
SUN
VENUS
CMa
Lep
Eri
Ant
Pyx
Lup
Cen
Col
Cae
Pup

To locate the moon in the sky, draw a line from the phase


6
5
4
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2
1
30
29
28
27
26
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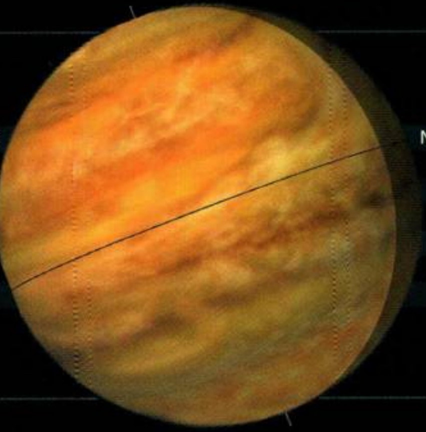
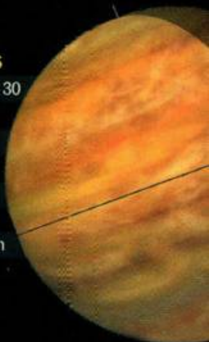
24
23
22
21
20

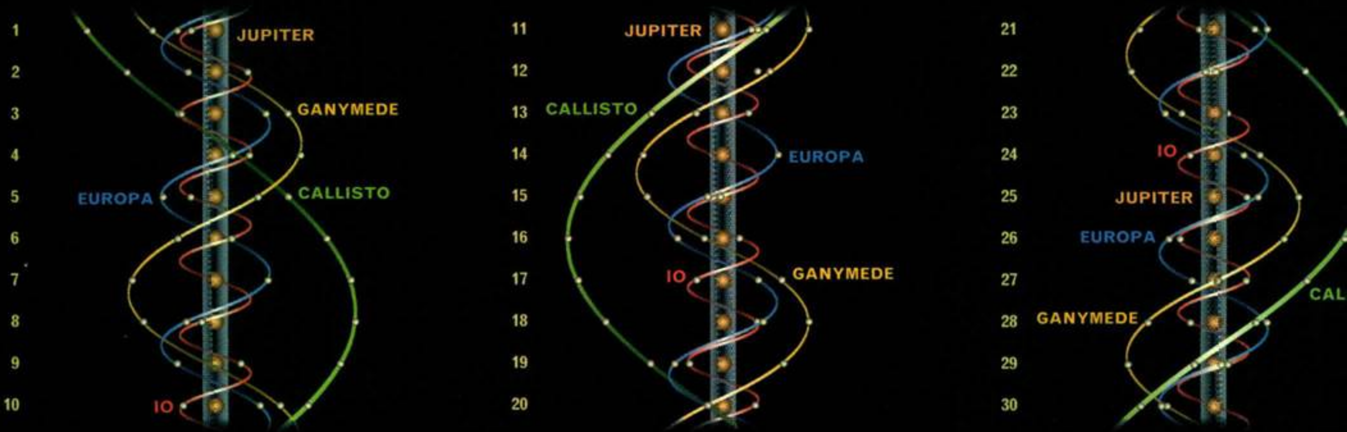
PLANETS	MERCURY	MERCURY	VENUS	VENUS
Date	November 1	November 30	November 15	November 30
Magnitude	–1.0	–0.7	–4.4	–4.6
Angular Size	5.0"	4.8"	56.2"	44.9"
Illumination	97%	97%	7%	20%
Distance (AU) from Earth	1.356	1.409	0.297	0.372
Distance (AU) from Sun	0.401	0.461	0.722	0.720
Right Ascension (2000.0)	13h53.7m	17h00.0m	13h51.7m	13h58.7m
Declination (2000.0)	–10°16'	–24°25'	–13°51'	–11°04'



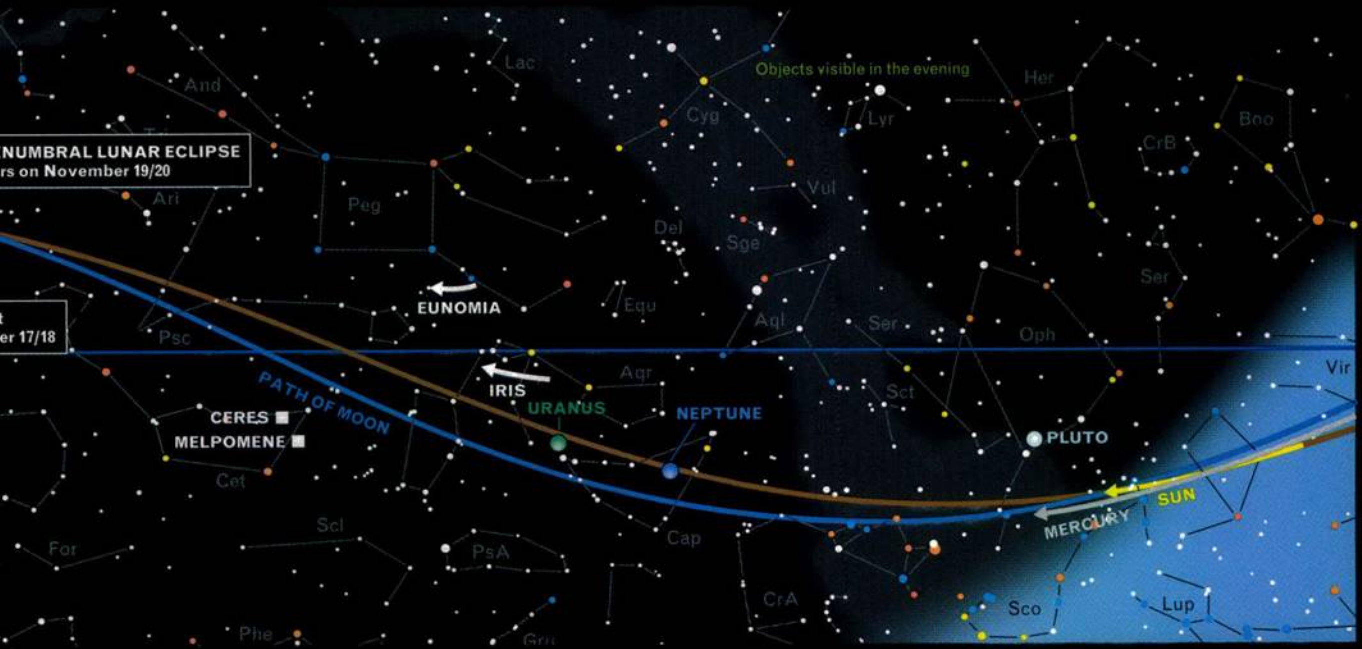


Jupiter's Moons

Dots display positions of Galilean satellites at 4 A.M. EST on date shown. South is at top to match the view in a telescope.



during the month.


And
Lac
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Objects visible in the evening
Lyr
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NUMBRAL LUNAR ECLIPSE
rs on November 19/20
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PATH OF MOON
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PLUTO
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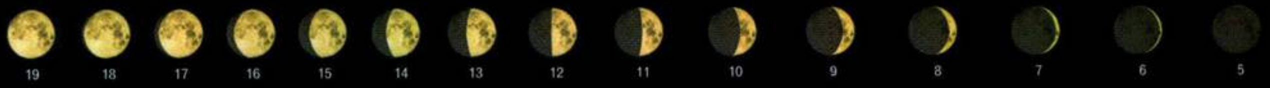
shown for the day straight up to the curved light-blue line.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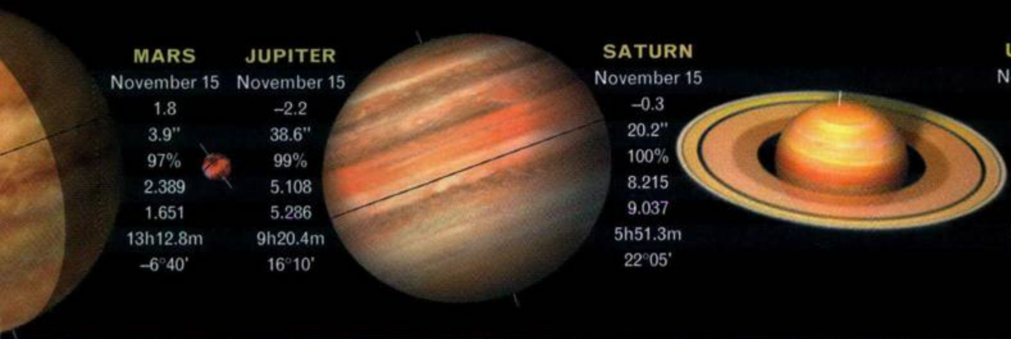
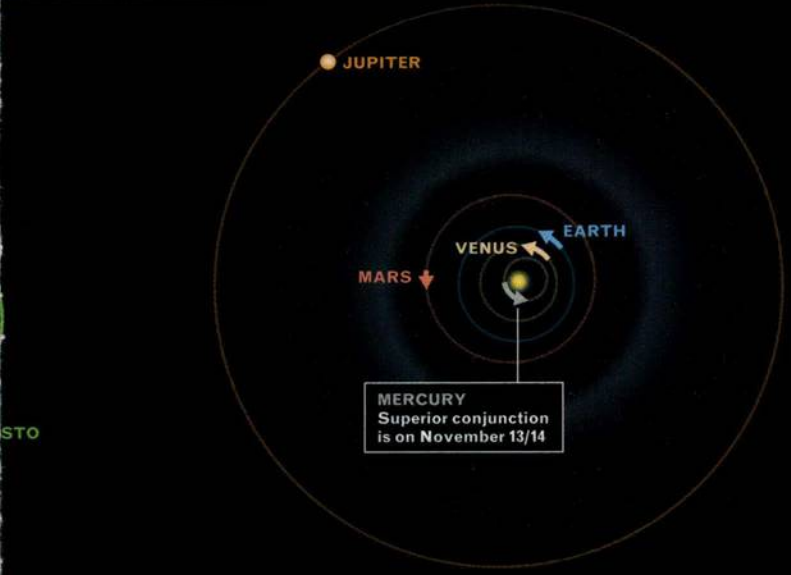


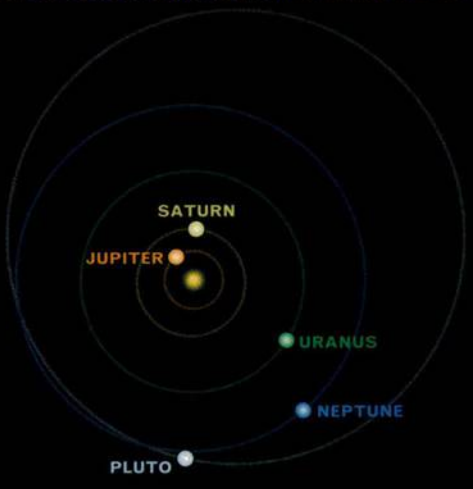
MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
November 15	November 15	November 15	November 15	November 15	November 15
1.8	–2.2	–0.3	5.8	7.9	13.9
3.9"	38.6"	20.2"	3.5"	2.3"	0.1"
97%	99%	100%	100%	100%	100%
2.389	5.108	8.215	19.944	30.311	31.466
1.651	5.286	9.037	20.011	30.086	30.577
13h12.8m	9h20.4m	5h51.3m	21h49.9m	20h43.0m	17h05.1m
–6°40'	16°10'	22°05'	–13°55'	–18°08'	–13°31'


JUPITER
EARTH
VENUS
MARS
STO

MERCURY
Superior conjunction
is on November 13/14

The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

Whale Watching

Beauty is found in all forms: the pulsating heart of a star, a filamentary web of gas, or a distant galactic swirl. The constellation Cetus the Whale is also a sight to behold. A large constellation, Cetus occupies much of the mid-evening sky toward the southern horizon (as viewed from the Northern Hemisphere). Only two bright stars lie within this region: Fomalhaut, the brighter and lower one, which belongs to the Piscis Austrinus (Southern Fish), and Beta (β) Ceti, which glows to the upper left.

During the dark-moon weekend at the start of the month, away from the obscuring effects of light pollution, set your binocular sights on Beta Ceti. Slide half a field downward (south), leaving Beta near the top and you'll see a wide triangle of stars near the bottom. A little bit above this group by about two apparent moonwidths, or 1°, is the dim oval glow of the galaxy NGC 247. The darker the sky, and the farther south you live, the easier it will be for you to observe this close galactic neighbor.

Lying some 10 million light-years away, NGC 247 displays a bright core surrounded by a dimmer oval halo in a 4-inch scope. With more aperture, an increasing number of foreground stars dot the celestial landscape. With a patient eye and a 12-inch scope you can begin to see mottling caused by a large number of stellar nurseries like the one found in our own Orion Nebula.

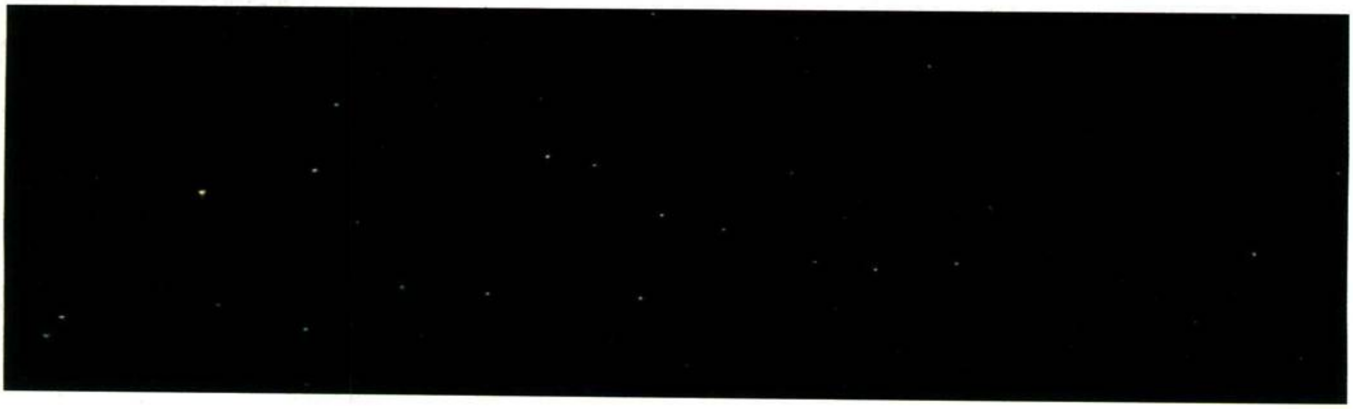
One of the sky's most popular planetary nebulae, NGC 246, is not far away on the north side of Beta Ceti. Slew your scope to a spot that forms the southern point of an equilateral triangle from Phi^1 (ϕ^1) and Phi^2 (ϕ^2) Ceti and you'll end up at this glowing disk first discovered by Sir William Herschel. The large circular haze (four times larger than the famous Ring Nebula) is actually a sphere of glowing gas left over from a dying star. This object reacts very well to a nebular or light pollution filter, so give it a try from the city.

On the evening of November 10, asteroid 1 Ceres lies close to a pair of 13th-magnitude galaxies: NGC 163 and NGC 165. To convince yourself that it's just masquerading as a supernova, revisit it after an hour to confirm its motion.

If you'd like to see something unpredictable in the sky, check out the irregular beat of the eruptive variable star WW Ceti. It will remain below visibility for a few weeks, then all of a sudden pop up to about 10th magnitude for a couple of days. A bloated red giant star is dumping its fuel onto a disk surrounding a blue-white hot companion, and when enough gas accumulates — boom (except there's no sound in the near vacuum of space); it shines away.

A close-up chart for WW Ceti can be found on the AAVSO (American Association of Variable Star Observers) web page: www.aavso.org (click on charts, and enter "ww cet" under star name). You can follow its activity using the light curve generator on the "Accessing data" page. The AAVSO has been instrumental in bringing the thrill of observing and recording variables to the public.

Right: Stellar nurseries thrive amidst the sparkling NGC 247. Anglo-Australian Telescope



Below: The figure of a whale is fairly pronounced in the constellation Cetus. Robert Mitchell

Gas Giants Creep into the Scene

Saturn is the dominant planet in the eastern sky during late November evenings. The more distant giant planets — Uranus and Neptune — become binocular objects as soon as the sky darkens. But you'll have to wait until the early morning hours to get a good peek at Jupiter.

Let's briefly check the positions of Uranus and Neptune. The two planets are visible for a few weeks longer before they get lost in the glow of the sun, when they approach their respective conjunctions with our star.

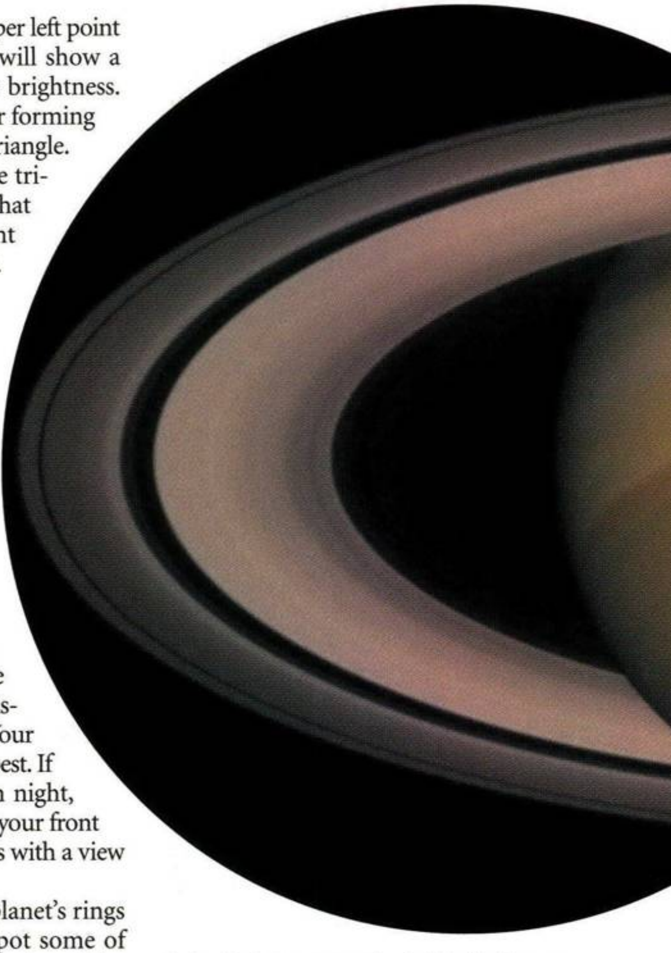
Neptune is the westernmost planet after sunset. You'll find it in the upper middle portion of Capricornus the Sea Goat. Neptune is best seen in telescopes, but binoculars and a good star chart will help you spot the magnitude 7.8 planet. A scope with high magnification will show less than a 3" disk.

Neptune is located near a star of similar magnitude, and less than 1° east of a magnitude-5.2 star, Upsilon (ψ) Capricorni. With the close proximity of Upsilon, the motion of Neptune will become apparent after two or three nights of observing.

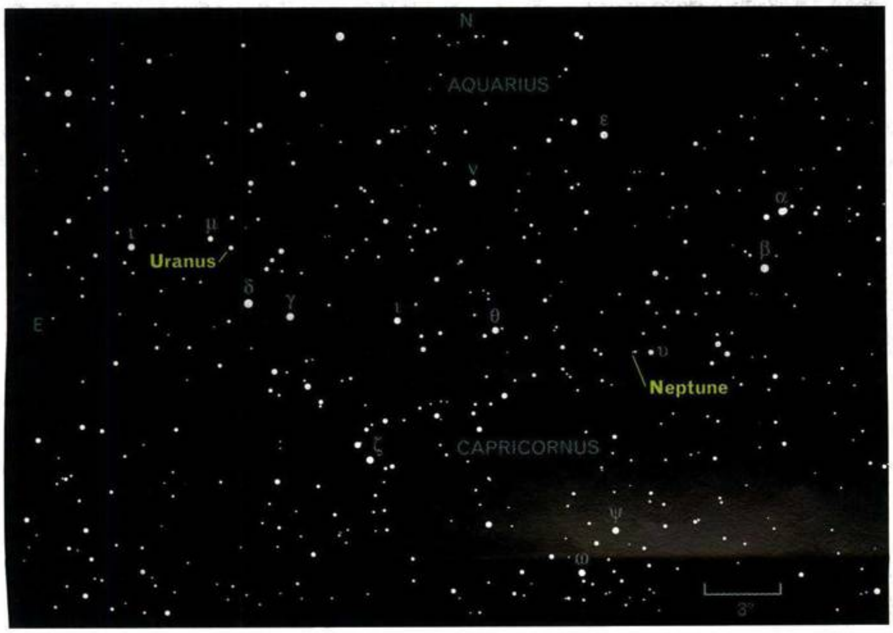
Uranus is an easier quarry. Shining at magnitude 5.8, you can catch the planet up to about three hours after sunset, when it sinks out of sight in the west. To the north of Deneb Algedi (Delta [δ] Capricorni), located in the upper left point of Capricornus, binoculars will show a row of three stars of similar brightness. East of this trio lies a lone star forming the point of a long isosceles triangle. Near this lone star within the triangle lies a dimmer object that will shift position from night to night. You've found Uranus.

Saturn rises mid-evening and shines brightly at a respectable magnitude –0.2. It's a month away from opposition. Saturn crosses from Orion back toward the horns of Taurus the Bull. A near full moon stands approximately 4° northwest of Saturn on November 21.

Nine months from now Saturn reaches perihelion. This year and next year the southern face of the rings is displayed at its widest possible. Your scope will show Saturn at its best. If you're outside on Halloween night, set up a portable telescope in your front yard and dazzle the neighbors with a view of the Ringed Planet.



Saturn's rings are punctuated by the famous Cassini Division. Hubble Heritage Team



The wide display of the planet's rings makes it an ideal time to spot some of the finer divisions within the rings. The most obvious, visible even in small scopes, is the Cassini Division, named after Gioavanni Cassini, the Italian astronomer who in 1675 first observed the "dark line" separating the bright rings into two parts.

Three principal rings are visible: Ring A is the outermost ring, Ring B — the brightest of all — lies just inside the Cassini Division, and Ring C (Crepe Ring) is a faint, semi-transparent ring lying closest to the planet. The Crepe Ring allows the body of Saturn to be visible through it.

There are other divisions within the ring system. The best known after Cassini's is Encke's Division, a very thin gap near the outer edge of Ring A — the outermost bright ring. Under good conditions an 8-inch scope might pick up this very thin gap. Controversial in its existence during much of the twentieth

century, Encke's Division showed up as a fine gap with finer ringlets within the gap in Voyager spacecraft images.

Cassini also discovered a number of Saturn's satellites, including Iapetus. Iapetus is the most unusual of Saturn's moons. It varies in brightness from magnitude 10.2, when west of Saturn, to 11.9, when east of the planet. In 1671 Cassini noted in his record book that the only explanation could be that Iapetus had a darker surface on one side — a hypothesis that was proven correct by Voyager spacecraft images. Throughout November Iapetus will move from east to west of Saturn, brightening as it does so. It passes due south of Saturn on November 10, and reaches western elongation on November 29.

Jupiter rises nearly four hours after Saturn. During November you'll have to wait until the hours after midnight to get a good view. Only then will it lie well above the horizon. Jupiter sits in a sparse region of sky in Cancer the Crab. Shining at magnitude –2.2, the planet dominates the early morning sky. Jupiter crosses into Leo late in the month, when the nearest bright star will be Regulus at magnitude 1.3. A waning last quarter moon stands 4° north of Jupiter on the morning of November 26.

The four bright moons of Jupiter are actually visible in tripod-mounted binoculars. Hand-held binoculars are impossible to hold steady enough to see these jovian satellites. Through a scope you can watch the nightly dance of these moons back and forth. With Jupiter near its west quadrature (90° angular distance from the sun), you can also see the satellites disappear into the shadow of the huge planet. From our earthly vantage point Jupiter's shadow extends out to the west.

The giant disk of Jupiter spans 40" across by the end of November, growing by almost ten percent during the month. This is the largest any planet appears in a dark sky (Venus can appear larger, but only in twilight). Such an apparent size allows telescopic observers to see plenty of features in Jupiter's dynamic atmosphere. The giant planet's rapid rotation carries these features across our view in a very short time.

Venus and Mars hang out together in the morning sky around dawn. Venus is dazzling, shining at magnitude –4.5 by November 30, having brightened by a half-magnitude during the month. This is the best month to view the fine growing crescent of Venus. It has just come out of inferior conjunction (passing between Earth and the sun) and rises earlier each morning.

By the third week of November our sister planet shines in a dark sky just as dawn breaks. From a slim 5-percent crescent on November 12, Venus shows a crescent reaching 13 percent by November 22, and 20 percent by month's end. As the crescent grows, the apparent size of the disk shrinks, indicating a growing distance between Earth and Venus.

Look for **Mars** rising in the east about two hours before sunrise by November 20. On this morning Mars stands 3° north of the 1st-magnitude star Spica in Virgo. Venus hangs 7° lower than Mars, outshining the Red Planet, which is a relatively dim magnitude 1.8. By November 30 only 2.4° separate the pair, and they both rise an hour earlier. On the same night the crescent moon hangs 15° above them, setting the stage for a spectacular conjunction on December 1, when all three objects lie within a 2° circle.

Mercury passes through conjunction with the sun on November 14, and will not be visible this month.

The crescent moon and Venus shine over a suburban neighborhood in Canada. Alister Ling

Meteors and Moons

Will the Leonids Strike Again?

Last year's Leonids were staggering for those observers lucky enough to find dark, clear skies. The heavens above North America and Asia lit up with, in some cases, thousands of meteors per hour. Some observers drove hundreds of miles to get a glimpse, and were justly rewarded with a spectacular show.

So what will happen this year? Most predictions indicate that this is the last chance of a Leonid storm for at least the next 30 years, and perhaps for a century. Predictions of a good display, even in light of recent successes, are always to be taken cautiously. It's not a guarantee that you'll see anything. Yet, as everyone found out last year, it's only those who are up and out of bed who might, perhaps, catch the most stunning sight of their lives. Perseverance is key to seeing a good meteor storm.

Here's the meteor prediction for 2002. There's a chance for some high storm rates this year. However, a waning gibbous moon will interfere, causing a large number of fainter meteors to be rendered invisible. David Asher and Rob McNaught of the Dutch Meteor Society favor a peak around November 19 at 10:36 UT (5:36 A.M. EST), which is a reasonable time for American observers. Another researcher who tracks the invisible streams of debris left by passages of comet Swift-Tuttle, Peter Brown, predicts an earlier peak at 03:50 UT on November 19 (10:50 P.M. EST on November 18). This prediction favors European observers. Earth passes closest to the comet's orbit on November 17 at 20:00 UT (3:00 P.M. EST). The timing of this potential event favors both Australia and Asia.

The radiant rises shortly after local midnight, and lies within the sickle of Leo the Lion, north of the bright star Regulus. The best direction to view is approximately 50° above the horizon and 60° away from the radiant.

Considering the brilliant meteors seen last year, efforts to view under a bright moon on the American mornings of November 18 and 19 are likely to still reward patient observers. Whether you will see a storm or not is uncertain. But to repeat last year's prediction, if you're not outside, you certainly won't see anything. So make a plan, watch the weather, find clear skies, and enjoy the sky as it's punctuated by dozens, hundreds, or even thousands of Leonid meteors.

The 2001 Leonid meteor shower staged a performance for observers worldwide. This streak was photographed in Japan. Hisatoshi Ogimoto

Penumbral Eclipse of the Moon

On the American evening of November 19 the moon slips into the penumbral shadow of Earth. The effect on the appearance of the moon is subtle. While the moon doesn't dip into the full shadow of Earth, or the "umbra," the moon's northern limb will appear slightly darker and more yellowish than normal. While the eclipse begins near local moonrise for observers in the United States, evidence of the eclipse is most pronounced during the central phase.

The eclipse begins at 6:32 P.M EST, with the maximum at 8:47 P.M EST. This is the largest penumbral eclipse of the year, with 88 percent of the moon's diameter in the partial shadow.

Callisto Makes Some Rounds

Attempt to observe the rare occultations, eclipses and transits involving the outer Galilean moon Callisto. The events listed in the adjacent table are given in Universal Time (Greenwich Mean Time) and Eastern Standard Time. Events that occur on either side of midnight are shown twice*, since the date changes for observers in Europe or the United States of America. Tr = transit; I = Ingress; E = Egress; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance. The events are worth viewing due to their relative rarity. Not all events are visible from the U.S.

Catch Callisto

UT	EDT	Events
Nov 3		
06:45	1:45 A.M.	IV.Ec.D.
11:29	6:29 A.M.	IV.Ec.R.
18:50	1:50 P.M.	IV.Oc.D.
23:43	6:43 P.M.	IV.Oc.R.
Nov 11		
17:13	12:13 P.M.	IV.Sh.I.
21:52	4:52 P.M.	IV.Sh.E.
Nov 12		
05:01	12:01 A.M.	IV.Tr.I.
09:47	4:47 A.M.	IV.Tr.E.
Nov 19		
	7:44 P.M.	IV.Ec.D.*
Nov 20		
00:44		IV.Ec.D.*
05:31	12:31 A.M.	IV.Ec.R.
12:38	7:38 A.M.	IV.Oc.D.
17:31	12:31 P.M.	IV.Tr.E.
Nov 28		
11:11	6:11 A.M.	IV.Sh.I.
15:52	10:52 A.M.	IV.Sh.E.
22:21	5:21 P.M.	IV.Tr.I.
	10:06 P.M.	IV.Tr.E.*
Nov 29		
03:06		IV.Tr.E.*

*** Events that occur on either side of midnight are shown twice.**

RX14's Prescription

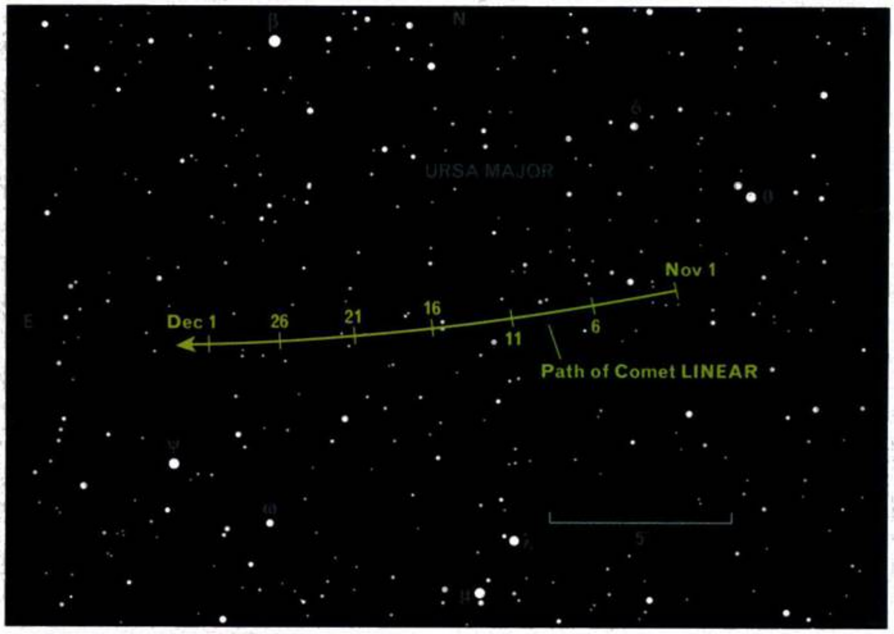
A great comet brings joy, and a nice one can cure the blues. The only thing Comet RX14 LINEAR is likely to give you this month is the chills. The best views of this fuzzball made of snow and dirt will come in the hours before dawn, when it's riding high overhead for Northern Hemisphere observers. Although it rises early evening, it skirts the northern horizon below Polaris. By midnight the comet is only 30° above the horizon — not the best for a good look.

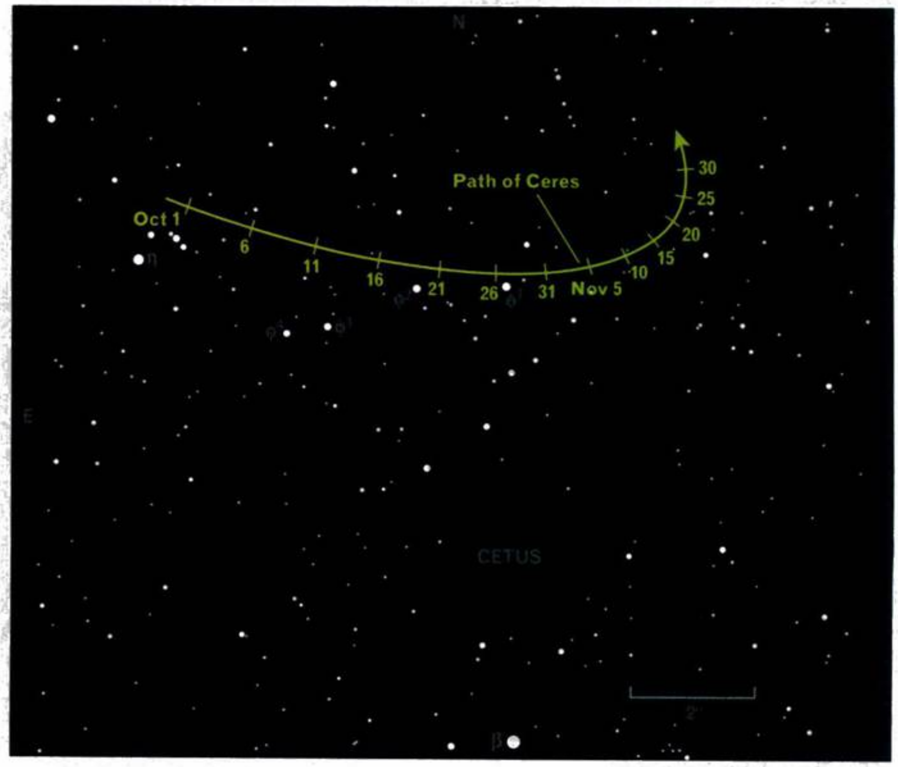
This month RX14 is sliding between the feet of Ursa Major at 11th magnitude. The good news is that over the next couple of months it will brighten slightly as it heads toward the large spiral galaxy M106. As it turns out, most of the galaxies along its path are fainter than 12th magnitude, so it won't be difficult to confuse RX14 with background objects. A 4-inch scope under a dark sky is probably the minimum you'd need to locate it.

You may be wondering why some comets are advertised well in advance, while other bright ones show up unexpectedly. Most anticipated comets are those with short orbits, which astronomers have known about for decades or even centuries. The rest are discovered in the distance while they are quite faint, and caught by robotic telescopes like LINEAR (Lincoln Near Earth Asteroid Research lab) or NEAT (Near Earth Asteroid Tracking). Last winter's discovery of LINEAR WM1 is a good example of this. Comets are usually found serendipitously as observers hunt down asteroids.

The surprise comets come from the deep south, where there are no roboticscopes to discover them. This means they can approach the inner solar system and brighten until vigilant amateur astronomers catch them. Observers often use small telescopes or even binoculars, and search mostly in the hours before dawn. Last spring's Ikeya-Zhang was discovered under such circumstances.

The next bright comet that observers await is NEAT C/2001 Q4, which is currently forecast to crest past 1st magnitude in May 2004. Of course this may turn out to be optimistic, but there's also a chance it could flare.





Ceres Cavorts in Cetus

Ceres should be a snap for suburban viewers. If you see a shiny spot indicated on the chart, you've bagged 1 Ceres. From country skies you can even follow its stately arc with binoculars.

The first asteroid discovered, the 570-mile (910 km) wide Ceres is truly a monster of a space rock. ■

Martin Ratcliffe is President of the International Planetarium Society. Alister Ling is a meteorologist for Environment Canada.

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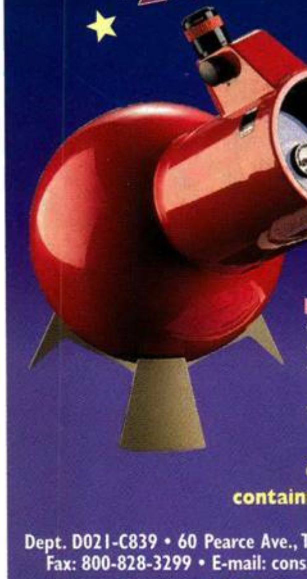

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FADE TO BLACK

The stage is set for next month's dramatic total eclipse of the sun. Here are a few tips to ensure the show gets rave reviews.

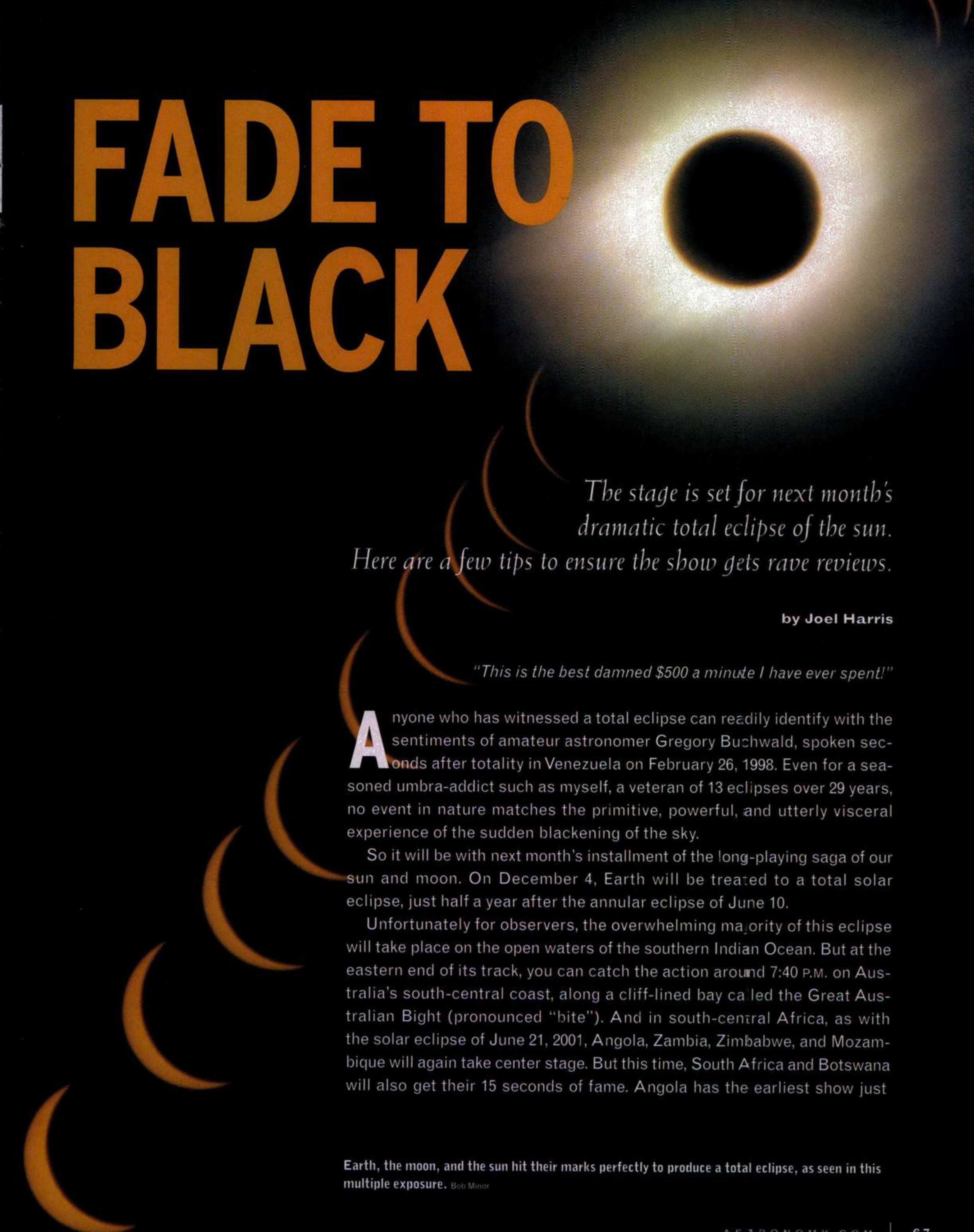
by Joel Harris

"This is the best damned $500 a minute I have ever spent!"

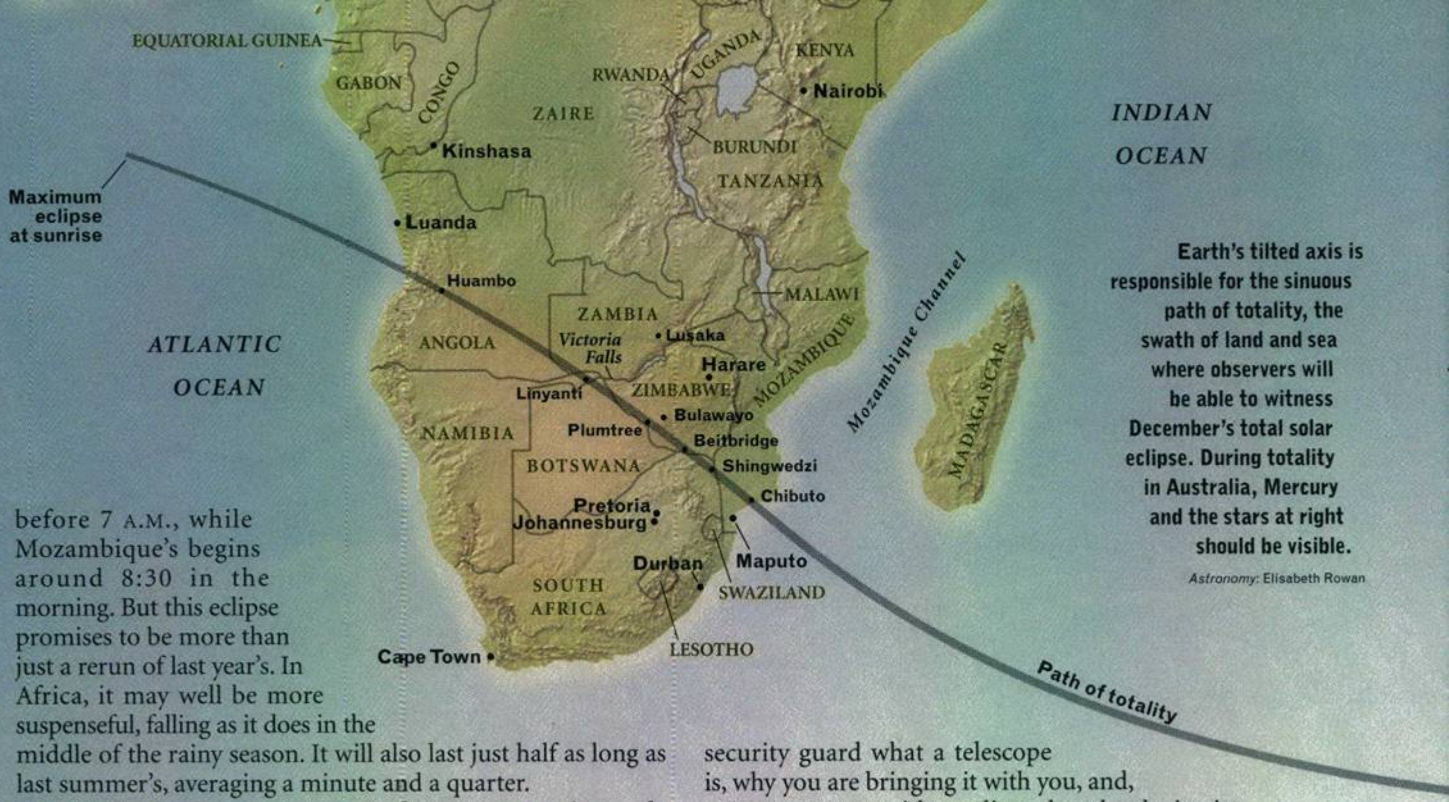
Anyone who has witnessed a total eclipse can readily identify with the sentiments of amateur astronomer Gregory Buchwald, spoken seconds after totality in Venezuela on February 26, 1998. Even for a seasoned umbra-addict such as myself, a veteran of 13 eclipses over 29 years, no event in nature matches the primitive, powerful, and utterly visceral experience of the sudden blackening of the sky.

So it will be with next month's installment of the long-playing saga of our sun and moon. On December 4, Earth will be treated to a total solar eclipse, just half a year after the annular eclipse of June 10.

Unfortunately for observers, the overwhelming majority of this eclipse will take place on the open waters of the southern Indian Ocean. But at the eastern end of its track, you can catch the action around 7:40 P.M. on Australia's south-central coast, along a cliff-lined bay called the Great Australian Bight (pronounced "bite"). And in south-central Africa, as with the solar eclipse of June 21, 2001, Angola, Zambia, Zimbabwe, and Mozambique will again take center stage. But this time, South Africa and Botswana will also get their 15 seconds of fame. Angola has the earliest show just



Earth, the moon, and the sun hit their marks perfectly to produce a total eclipse, as seen in this multiple exposure. Bob Minor


EQUATORIAL GUINEA
GABON
CONGO
ZAIRE
RWANDA
UGANDA
KENYA
Nairobi
Kinshasa
BURUNDI
TANZANIA
INDIAN OCEAN
Maximum eclipse at sunrise
Luanda
Huambo
MALAWI
Mozambique Channel
ZAMBIA
ANGOLA
Victoria Falls
Lusaka
Harare
MOZAMBIQUE
ATLANTIC OCEAN
Linyanti
ZIMBABWE
MADAGASCAR
Bulawayo
NAMIBIA
Plumtree
Beitbridge
BOTSWANA
Shingwedzi
Chibuto
Pretoria
Johannesburg
Durban
Maputo
SOUTH AFRICA
SWAZILAND
Cape Town
LESOTHO
Path of totality

Earth's tilted axis is responsible for the sinuous path of totality, the swath of land and sea where observers will be able to witness December's total solar eclipse. During totality in Australia, Mercury and the stars at right should be visible. *Astronomy:* Elisabeth Rowan

before 7 A.M., while Mozambique's begins around 8:30 in the morning. But this eclipse promises to be more than just a rerun of last year's. In Africa, it may well be more suspenseful, falling as it does in the middle of the rainy season. It will also last just half as long as last summer's, averaging a minute and a quarter.

With the sky show soon to start, observers are getting ready to make their way to the theater. Most eclipse chasers seem to be heading Down Under next month, not only because there's a better chance for good weather, but also because many enthusiasts visited Africa last year (the "Been There, Done That" syndrome). Whether your venue is in Australia or Africa, here are a few suggestions to make your trip a smooth one.

First, be sure to keep current on the health, political, and travel conditions of the country you intend to visit. The U.S. State Department has a very good website at travel.state.gov/travel_ warnings.html, where you can access a large database to find information about your destination. An extremely useful site for health is the Centers for Disease Control and Prevention at www.cdc.gov/travel.

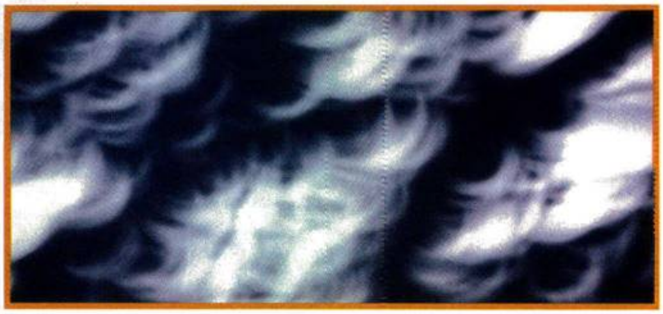
For those traveling to Australia, take advantage of a service that makes obtaining a tourist visa easy. Visit www.migrationint.com.au/temporary_short_stay_visa.html for an Electronic Tourist Visa (ETV) that lasts up to three months.

Second, travel as lightly as possible. Especially in the aftermath of September 11, overloading yourself with marginally useful items — particularly carry-on goods — will only complicate your trip. Who wants the hassle of explaining to every security guard what a telescope is, why you are bringing it with you, and, appearances notwithstanding, that the device is actually not a bazooka or a mortar launcher. Those trekking to Australia this month should think twice about lugging that 12-inch scope 8,000 miles each way across the Pacific. Totality lasts a mere 33 seconds on the coastline, near the town of Ceduna, and a scant 25 seconds farther inland, in the vicinity of Lyndhurst.

Third, remember one of the cardinal rules of eclipse observation: Don't spend the entire duration of totality with your eyeball glued to an eyepiece or camera viewfinder. The very brief totality demands that you keep photographic plans simple. Personally, I am bringing a medium-focal-length telephoto lens, my 35mm SLR camera, and a tripod. My plan is to take about six or seven pictures during those precious moments, and then throw my head back and gawk at the sky. If you're part of a tour, you may be able to set up a photographic buddy system, wherein you agree to share your shots, lessening the pressure of catching everything yourself.

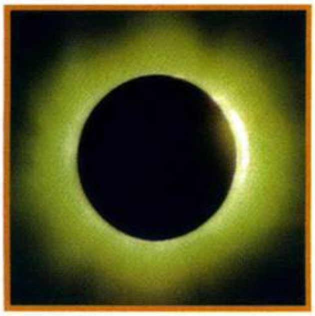
Fourth, be sure to travel well prepared. If your batteries for that digital camera suffer an acute power failure, there's no Wal-Mart or Costco around to save the day. If there are supplies at all, they will likely cost more than at home.

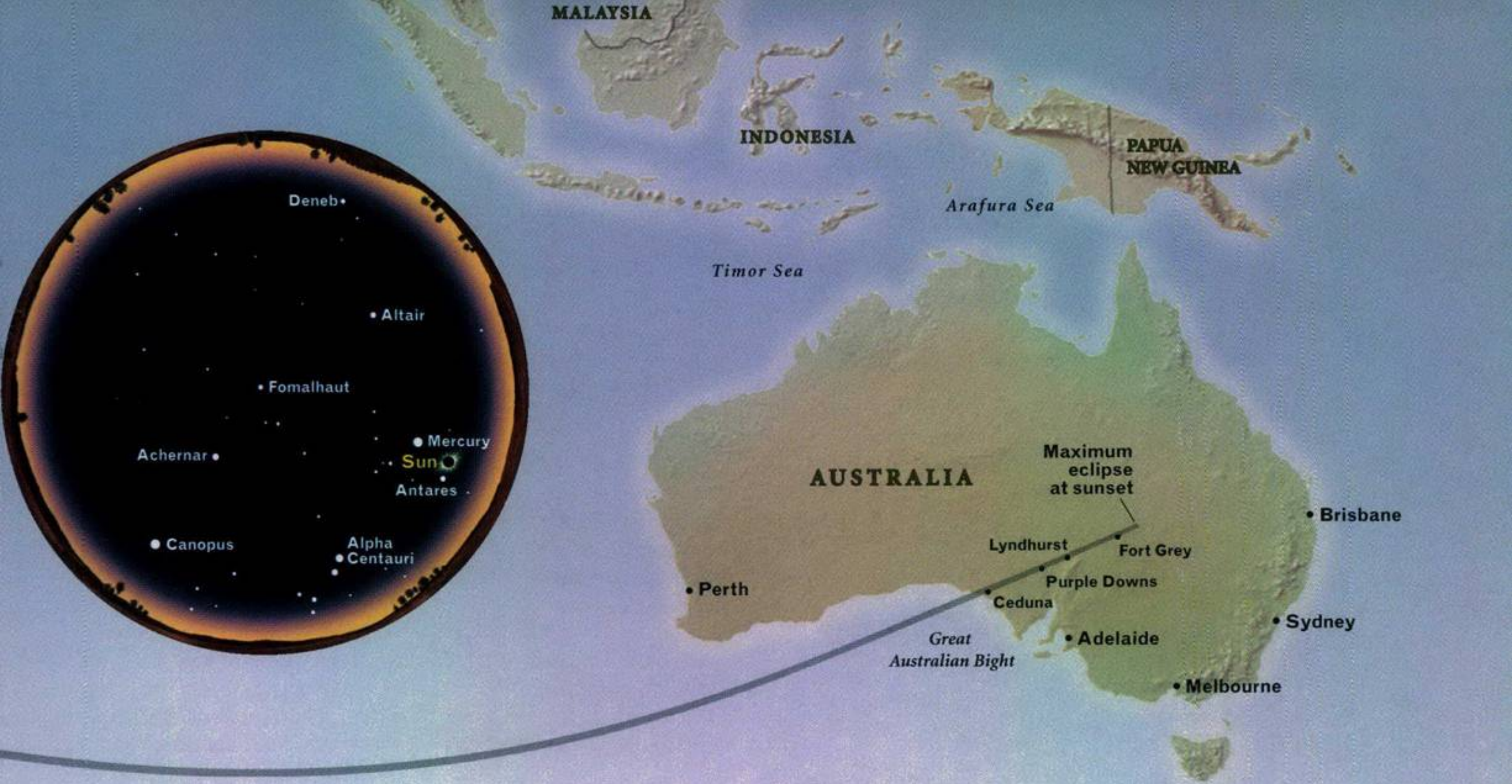
Not all the action takes place in the sky during an eclipse. Keep an eye on the ground to see the crescent sun's shadowplay through leaves. The openings between them act as pinholes for light. Pierre Schintone



Sunlight seeps through a deep gorge to produce the diamond ring effect. Roland and Marjorie Christen

The corona extends for millions of miles and is visible only when the sun's disk is hidden. Ryszard Sihiec




MALAYSIA
INDONESIA
PAPUA NEW GUINEA
Arafura Sea
Timor Sea
AUSTRALIA
Maximum eclipse at sunset
Brisbane
Lyndhurst
Fort Grey
Purple Downs
Perth
Ceduna
Sydney
Great Australian Bight
Adelaide
Melbourne
Deneb
Altair
Fomalhaut
Mercury
Achernar
Sun
Antares
Canopus
Alpha Centauri

Be sure to take an abundant supply of medications, first aid supplies, toiletries, and insect repellant with you. Both Africa and Australia will be in the midst of bug season, and anyone who traveled to Australia for either Comet Halley in 1986 or for the 1999 annular eclipse can attest to the relentless attacks of indigenous flies.

Bring copious amounts of your favorite sunblock and a large-brimmed, flexible hat to protect you when the sun's light is not being blocked by the moon. The average daily maximum temperature in the Outback region of Australia is 32° C (90° F), but highs can frequently reach 40°C (104° F).

Savor the experience, however hot and buggy it turns out to be, because next month's event is the last highly accessible total eclipse until March 29, 2006. Until then, eclipses are far-flung and sure to be pricey: A total eclipse will darken a swath of ice next December in Antarctica, an annular eclipse will hit Iceland next May, and a hybrid (annular-total) will present a spectacle for some lucky fish in the southeastern Pacific Ocean on April 8, 2005.

Bear in mind a few final thoughts, born of the many years I have been fortunate enough to travel the world in pursuit of the moon's shadow. Even if your trip ends in a clouded-out event, you still have a lot to enjoy. Both Africa and Australia are wonderful, exotic, thought-provoking destinations. The 15-hour-plane trip will be well worth the wait.

And if the weather doesn't cooperate, don't lose heart. In June, I went to Mexico to observe the "Ring of Fire" annular eclipse at sunset. Setting up on a beach south of Puerto Vallarta, I was frustrated by cloudy skies all day — not a patch of blue was in sight. But a mere five minutes before annularity ended, the sun dropped down into a very narrow seam in the overcast sky, permitting pilgrims like me to see and photograph it. The moral is, don't give up. Some pretty remarkable things can and do happen, even when all hope seems lost. So good luck, and clear skies to everyone! ■

Joel Harris is an engineer in Torrance, California, and co-author of Chasing the Shadow: An Observer's Guide to Eclipses.

Fiery red arcs of gas called prominences were once thought to be part of the moon. Patrick Martinez

Cooler than the rest of the corona, prominences are controlled by the sun's magnetic field. Luc Viatour

The view below is similar to the one observers in Australia will see during totality, when the veiled sun will hang low over the Great Australian Bight. Michael Maunder

ask Astro

Solar Eclipses, Viewing Earth from Space, Galileo's Future

When the moon passes in front of the sun, it can properly be called both an eclipse and an occultation. Luc Viatour

While reading Arthur C. Clarke's *3001 — The Final Odyssey*, I came upon a character who, being situated on Ganymede, said that he "watched Europa eclipse — sorry, occult — Io." I immediately went for my trusty astronomy glossary and observed that an occultation is the "hiding of one astronomical body by another" and that an eclipse is "the passage of all or part of one astronomical body into the shadow of another." So, during a solar eclipse, is the sun eclipsed by the moon, or would this phenomenon be more accurately described as an occultation of the sun by the moon?
— Joe DiRienzo, Tuckahoe, New York

Keep hold of that astronomy glossary — it serves you well. You've stumbled into an area where the English language can't quite do justice to the complexities of nature. An occultation occurs when one object hides another from view by passing between it and an observer. As the moon makes its way around the sky each month, it's always passing in front of distant stars and blocking them from view. These events are called lunar occultations, and similar events occur when planets or asteroids pass in front of stars.

If you think about it, the same geometry is at work when the moon passes in front of the sun. So a solar eclipse is, by definition, an occultation. (Though a lunar eclipse is not because no object comes between the moon and Earth.)

An eclipse, on the other hand, involves one object passing into the shadow of another — a feat accomplished at both solar and lunar eclipses. But again, if you think about the moon occulting a distant star, it is technically casting its shadow on Earth and eclipsing the star. To avoid confusion, and to keep the terminology consistent with lunar eclipses, astronomers invariably refer to solar eclipses as eclipses. By the same reasoning, a solar system object passing in front of a distant star is always referred to as an occultation.

As Arthur C. Clarke found out, the situation is a little easier to understand at Jupiter, where several non-luminous bodies can come into play. Each of Jupiter's four large moons can pass in front of any other as it orbits the planet, causing an occultation. Similarly, any of the moons can pass between the sun and another moon, casting its shadow and creating an eclipse. Only in those rare instances when the sun and the involved moons all line up will an eclipse coincide with an occultation. — *Richard Talcott, senior editor and co-author of* Chasing the Shadow: An Observer's Guide to Eclipses

Can you see the Great Wall of China and the great pyramids of Egypt from the moon? How about from the space shuttle?
— Roberto Valledor, Chile

The first of these is an "urban myth" that has persisted for years. The answer is no — by a long shot. However, the second part of the question proves a bit more interesting.

A person with excellent vision can resolve 1/60 of a degree with the unaided eye. This is purely a function of the eye's lens, the cornea, casting an image of the outside world onto a set of detail-detecting photoreceptors in the retina. (Incidentally, the retina's densest portion, called the fovea region, has an astonishing 180,000 receptors per square millimeter.)

We know that the farther away from something we get, the smaller it appears. The angle it makes in our field of vision gets smaller as the distance increases. If something's apparent size becomes less than 1/60 of a degree, we can't resolve it with the naked eye. (That's where the magnification provided by binoculars or a telescope comes in handy.)

This said, let's use simple trigonometry to calculate how small the pyramids and Great Wall would appear from the moon. The base of the largest pyramid at

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The great pyramids at Giza are barely big enough to resolve from Earth orbit, but way too small to see from the moon. NASA

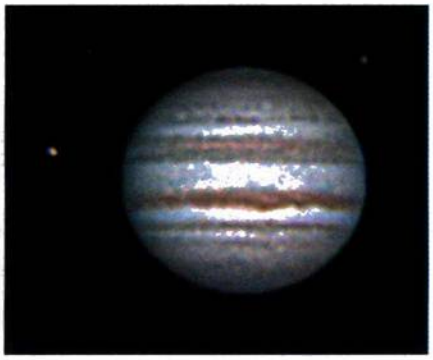
Giza measures 751 feet a side. Assuming the moon's average distance is about 240,000 miles, the pyramid's angular size would be microscopically small: a little more than 1/30,000 of a degree. This is about 500 times smaller than the smallest angle the eye can discern. The Great Wall would be even tougher to spot because it appears even smaller. Remember that when astronauts were traipsing across the moon some 30 years ago, they had a hard-enough time detecting Earth's *continents*.

These sights get much easier when viewed from the shuttle. The shuttle orbits some 240 miles above Earth, a thousand times closer than the moon, so objects on Earth appear a thousand times larger. That makes the largest pyramid about 1/30 of a degree wide, within range of a sharp-eyed astronaut. The Great Wall's width puts it near the human eye's threshold.

U.S. astronaut Andy Thomas, who flew aboard the MIR space station in 1998, had this to say about earthly sights: "Evidence of human habitation is visible from low Earth orbit. Cities can be seen, although, surprisingly, they do not stand out readily. But we can make out their grid-like patterns of streets. In remote areas, certain roads and railway lines can be seen as faint lines across the Earth. The stories about the Great Wall of China being visible from space may be true, but I have yet to see it." — *John Shibley, contributing editor*

As I understand it, the current end-of-mission plan for the Galileo spacecraft is to destroy the probe by having it enter Jupiter's atmosphere or crash-land on one of its moons. Why doesn't NASA plan a gravity assist using Jupiter or one of its satellites to eject the craft back into (or out of) the solar system in order for it to continue doing useful science? — *John Walker, Elko, Nevada*

Many options were considered before placing the Galileo spacecraft on its present orbit, which will see it plunge into Jupiter's crushing atmosphere in September 2003. The current orbit was determined back in 2000 and involved several considerations. Near the top of the list was the uniqueness of the cooperative science that was possible between the experiments on the Cassini and Galileo spacecraft when Cassini flew past Jupiter in December 2000. After those



After giving unprecedented views of Jupiter and its four large moons during the past six years, the Galileo spacecraft will plunge into the giant planet in September 2003. NASA/JPL

successful observations, NASA decided to continue science operations, and the spacecraft made one flyby of Callisto and three of the volcanic moon Io.

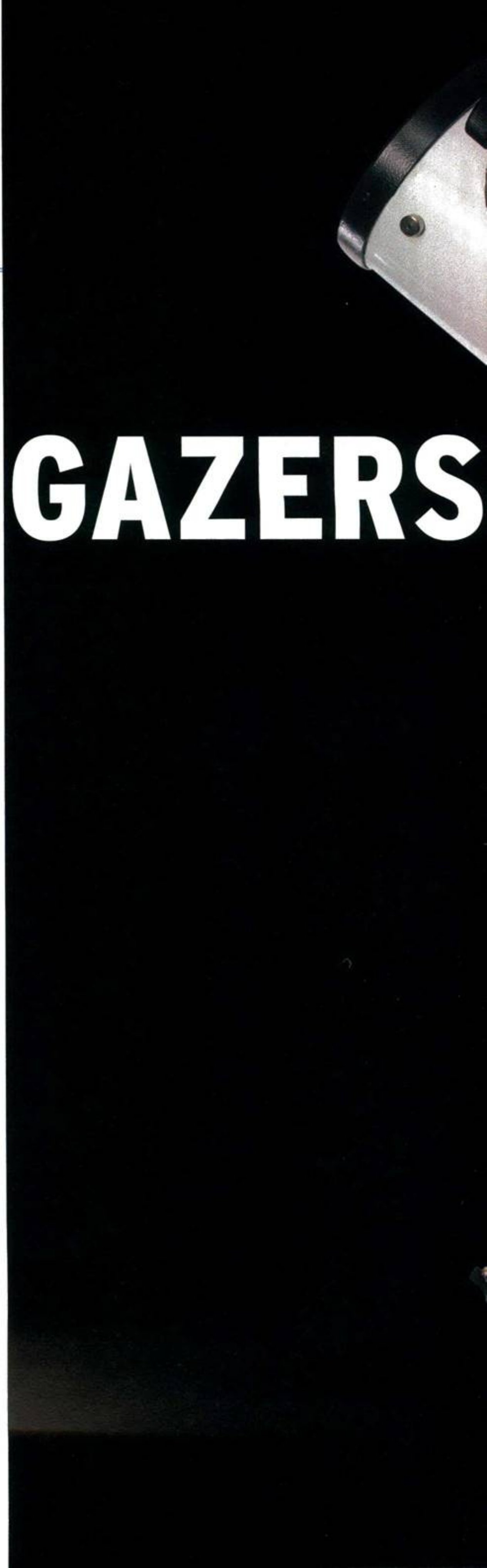
Because of the expected science return, NASA chose to do this despite the cost (which was large and had to be considered in the context of other uses of the money) and the state of the spacecraft and its instruments. But now, after seven years of exposure to Jupiter's extreme radiation environment, the spacecraft's electronics are well beyond their expected lifetime, and showing it. Radiation effects killed a significant fraction of the science planned during one Io flyby and almost all of the observations during the final flyby. Galileo is also nearly out of its hydrazine propellant, which is needed to keep its antenna pointed toward Earth. So even if good science seemed likely in the future, there would be no way of returning the data.

Galileo's current trajectory puts it on course for one final flyby — the only encounter with Jupiter's inner moon Amalthea — on November 5. Galileo will then loop around Jupiter once more before heading into the planet next September. This trajectory has the support of the project and its scientists because it removes the spacecraft and its two nuclear generators from the Jupiter system. Just as important, it will prevent any inadvertent contamination of the Galilean satellites, particularly Europa, which some scientists believe could harbor life in a subsurface ocean. — *Michael J. S. Belton, President, Belton Space Exploration Initiatives, LLC. He is the Imaging Science Team Leader for Galileo and deputy principal investigator for both the CONTOUR and Deep Impact projects.*

Astronomy reviews three popular first-time telescopes

By Phil Harrington

SCOPING OUT THE NEW STARGAZERS



Many newcomers to astronomy are drawn to the increasingly popular computerized telescopes. Admittedly, they do have a certain appeal — you simply tell the telescope what you want to observe, and then it steers itself to the target automatically.

While these "Go-to" scopes may be the answer for some, they certainly are not for others. Many stargazers prefer to observe the night sky the old-fashioned way by learning the stars and finding objects on their own. For this type of novice, one of the most popular first-time telescopes, especially for young astronomers, is a 4.5-inch Newtonian reflector on a German equatorial mount. How many of us "old timers" started out with that kind of instrument? Probably quite a few. They offer basic transportation to the stars, while not overwhelming the user with too many bells and whistles.

Unfortunately, many such instruments have inherited the label "department-store telescopes." These telescopes are often characterized by poor optics, subdiameter eyepieces, wobbly mounts, and woefully small finderscopes.

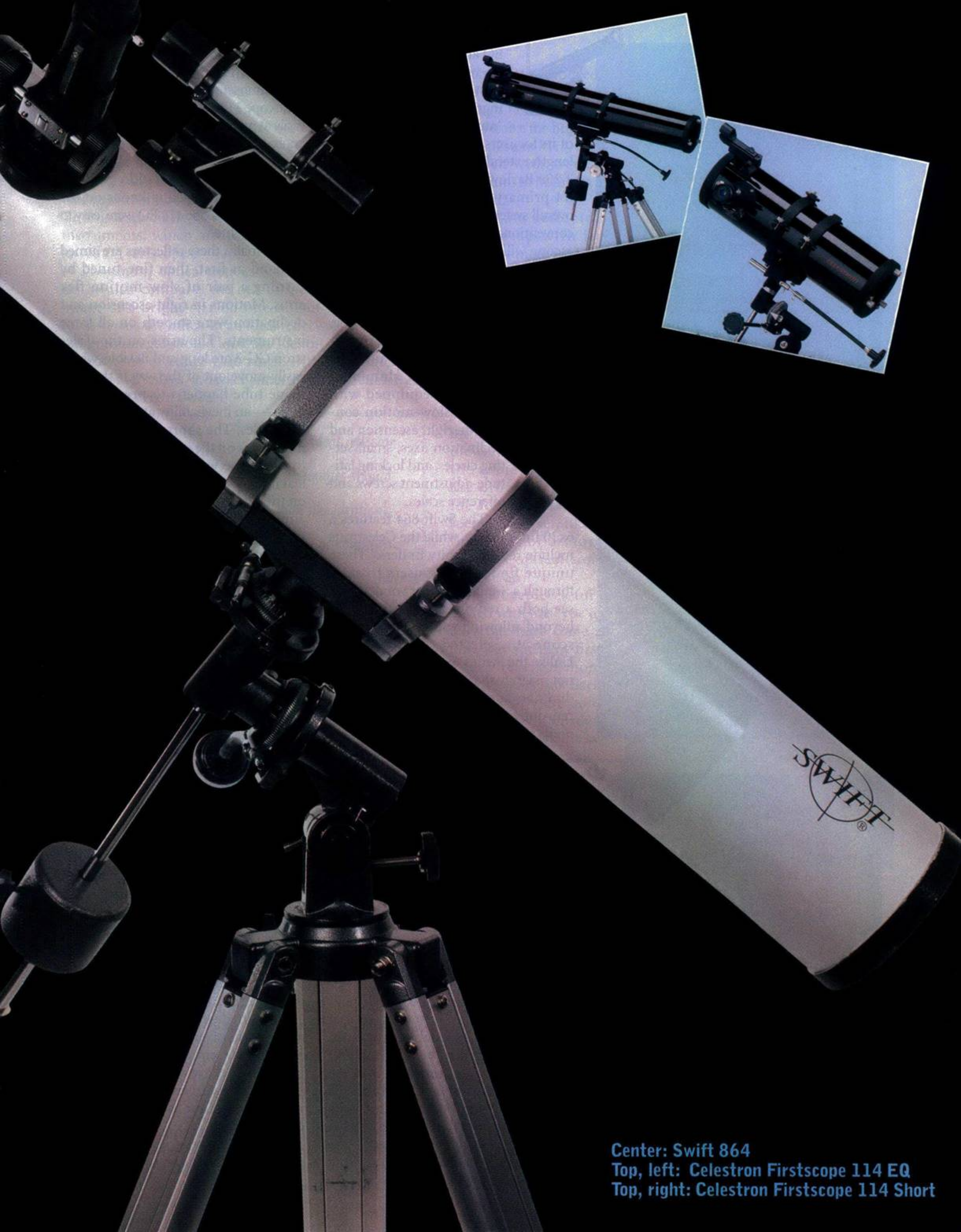
Noting this, several companies upgraded their line of beginner telescopes. The three instruments evaluated here are some of the results. All include rack-and-pinion focusers that accept standard 1¼" eyepieces, reasonably sturdy mountings, and usable finders.

I recently compared three 4.5-inch Newtonian reflectors: The Celestron Firstscope 114 EQ, the Celestron Firstscope 114 Short, and the Swift 864. All were compared side-by-side from my suburban backyard on Long Island under viewing conditions typical for most *Astronomy* readers and potential consumers.

Standard Equipment

One look at the three telescopes side-by-side and it's immediately clear that all are not the same "under the hood." The Celestron Firstscope 114 Short is much shorter than the others. However, if you look at their specifications, you'll find that all three telescopes have roughly the same focal length.

While the Swift 864 and Celestron Firstscope 114



Center: Swift 864
Top, left: Celestron Firstscope 114 EQ
Top, right: Celestron Firstscope 114 Short

Celestron

Firstscope 114 EQ

Celestron International
2835 Columbia Street
Torrance, CA 90503
Phone: (310) 328-9560
Web site: http://www.celestron.com
Aperture: 4.5 inches
Focal ratio: 8
Focal length: 36 inches (910mm)
Configuration: Traditional Newtonian reflector
Weight: 19 pounds
Standard equipment: 1.25" rack-and-pinion focuser
10mm and 20mm Modified Achromat (MA) eyepieces
Star Pointer unity finder
Manual dual-axis slow-motion controls
German equatorial mount
Typical Retail Price: $230

Celestron

114 Short

Aperture: 4.5 inches
Focal ratio: 9
Focal length: 40.5 inches (1030mm)
Configuration: Shortened Newtonian reflector
Weight: 16 pounds
Standard equipment: 1.25" rack-and-pinion focuser
10mm and 20mm Modified Achromat (MA) eyepieces
Star Pointer unity finder
Manual dual-axis slow-motion controls
German equatorial mount
Accessory tray
Adjustable aluminum tripod
Typical Retail Price: $230

Swift

864

Swift Instruments, Inc.
952 Dorchester Avenue
Boston, MA 02125
Phone: (617) 436-2960, (800) 446-1116
Web site: http://www.swift-optics.com
Aperture: 4.5 inches
Focal ratio: 8
Focal length: 36 inches (910mm)
Configuration: Traditional Newtonian reflector
Weight: 23 pounds
Standard equipment: 1.25" rack-and-pinion focuser
10mm and 25mm Plössl eyepieces
6x30 finderscope
Manual dual-axis slow-motion controls
German equatorial mount
Accessory tray
Adjustable aluminum tripod
Typical Retail Price: $495.00

EQ are traditional Newtonian reflectors, the Celestron First 114 Short has an extra ingredient: An achromatic "auxiliary" lens in the base of its focusers, which serves as a focal-length extender — in effect, a built-in 2.25x Barlow lens. This lens takes the f/4 primary mirror and extends the overall system focal ratio to f/9. (Unlike conventional Barlows, however, the telescope will not come to a focus without this auxiliary lens in place.) As a result, the telescope's length and weight is reduced, making the 114 Short easier to carry in and out for a night's observing.

All of these telescopes come on light-duty German equatorial mounts perched atop adjustable, aluminum tripods. And all are equipped with manual slow-motion controls on right ascension and declination axes, small setting circles, and locking latitude-adjustment screws and reference scales.

The Swift 864 features a 6x30 finderscope, while the Celestrons include red-dot "unity finders." These unique finders allow users to stare through a ⅞-inch diameter window and see both a red dot as well as the sky beyond, allowing you to aim the telescope at a selected celestial target. Unlike the Swift's 6x30 finder, these do not magnify the view nor do they make dim stars appear brighter. In fact, each red-dot finder has a reddish coating on its window that reduces star brightness by one-half magnitude.

Finally, the telescopes all come with two or more 1 ¼" eyepieces. The Celestron Firstscope 114 EQ includes 10mm and 25mm Modified Achromat (MA) eyepieces, while the Firstscope 114 Short comes with less spectacular 6mm and 20mm Huygenian eyepieces. The Swift 864 comes with 10mm and 25mm Plössl eyepieces — the best of the bunch.

Mechanics

As already mentioned, each telescope comes on a German equatorial mount and an adjustable aluminum tripod. The sturdiest (but also heaviest) mount is the CG-3 supplied with the Celestron Firstscope 114 EQ. The Swift mount proves sturdy enough for its telescope, as does the small mount for the Celestron "short" telescope.

To keep the telescope from shifting its aim, each mount has locking screws on both axes. They worked well, although the thumbscrews used on the Celestron Firstscope 114 Short are too small to find easily at night. Although larger, the Swift's knobs were inconveniently placed; I often found myself brushing up against the gearing instead, getting its sticky grease on my fingers. The locking knobs on the Celestron Firstscope 114 EQ were easy to find and tighten.

Normally, these reflectors are aimed by hand at first, then fine-tuned by turning a pair of slow-motion flex arms. Motions in right ascension and declination were smooth on all three instruments. The arms on the Celestron GG-3 are long and flexible, which easily move out of the way if the telescope tube happens to press against them — an inevitability at certain viewing angles. The shorter, stiffer adjustment arms on the other mounts tended to get in the way. In fact, I ended up leaving off the right-ascension arms on the other scopes and adjusted their aim by turning small wheels on the right ascension axes instead.

Each telescope holds its primary mirror in place using a metal push-pull style cell. These involve three pairs of screws. One screw in each pair pushes against the inner portion of the cell that holds the mirror, while the second pulls on it to equal out the force. Loosen one in the pair and turn the other to adjust the primary's collimation. The Celestron cells use nice, knurled knobs for adjusting the mirror's tilt and a Phillips screw to lock everything into place. The Swift, however, forces one to use a Phillips screwdriver to adjust the mirror's tilt, which is less convenient.

At the other end of the tube, the secondary-mirror holders are fully adjustable, requiring a small Phillips screwdriver to change the mirror's tilt. The Celestrons use single-vane mounts, while the Swift uses a three-vane spider.

Optics

Each telescope was shipped to me directly from its respective company and outfitted with the standard equipment previously mentioned. The assembly of each went quickly and without incident. I believe a rank novice could put any of these instruments together in well under an hour using the tools supplied with each.

Once everything was assembled, I gave each telescope a quick once-over.

I discovered that all but the Celestron Firstscope 114 EQ were out of optical collimation. The primary mirror in the Celestron Firstscope 114 Short needed adjustment, while both the primary and secondary mirrors in the Swift needed attention. Improperly collimated optics will inevitably decrease image quality. This is especially true with "short" instruments, which are, in effect, Barlowed f/4 telescopes.

I began my optical tests with the star test, which compares the out-of-focus image of a bright star on one side of focus versus the other. In an ideal reflector, both images should look like identical patterns of concentric rings, with bright outer edges, a darker inner portion, and a bright point in the center. If the two images disagree, then there is a problem, either in the optics or from atmospheric turbulence. A telescope must be properly cooled before attempting the star test, so I left each outside for two hours before I began.

> *"In an ideal reflector, both images should look like identical patterns of concentric rings, with bright outer edges, a darker inner portion, and a bright point in the center."*

Both the Swift and Celestron Firstscope 114 EQ showed the best test results. Indeed, subsequent viewing proved both had very good optics; I subjectively judged an overall system wavefront of better than ¼ wave. That's quite impressive for an "economy" telescope. The Swift showed similar low levels of spherical aberration. The Celestron Short reflector was clearly inferior to the others.

After the star test, I wanted to know how the scopes perform on actual objects. Again the Celestron Firstscope 114 EQ and Swift scopes rose to the top. I was especially impressed with Saturn — a very revealing object. Cassini's Division was clearly and cleanly visible at 76x in both scopes. Mixing eyepieces, Saturn remained surprisingly crisp through both, especially with the Swift, using a 4mm eyepiece (230x). The rings were much fuzzier through the Celestron Short.

I had similar results with Jupiter. The planet's many bands were best seen through the Celestron Firstscope 114 EQ, followed closely by the Swift 864.

Deep-sky objects showed well through all three telescopes, but especially the Celestron Firstscope 114 EQ and Swift 864. Both split the Double-Double in Lyra nicely at 100x. Indeed, they also showed the elusive companion of Rigel at 76x, a tough task for a 4.5-inch telescope. I could resolve the brighter members of globular clusters M13, M2, and M15 through each with averted vision, while the Trapezium in M42 was a simple task through both.

The Celestron Short reflector could not quite keep up with its longer siblings. For instance, resolution of the Double-Double was possible but was not as crisp as through the others. I believe this effect was the combined result of increased spherical aberration and impact of the auxiliary lens used to stretch the focal length. I also found that focusing the "short" telescope was more difficult. Although the focuser is essentially the same as that on the other Celestron, the focusing motion seemed coarser, likely the effect of a more complex optical configuration.

The eyepieces furnished with this type of telescope have come a long way since my first 4-inch reflector more than 30 years ago. Back then most were sold with 0.965" Ramsden eyepieces that were basically worthless. The Modified Achromats are superior to those, but can still be improved upon. The Swift 864 comes with 10mm and 25mm Plössl eyepieces, easily the best of the bunch. My recommendation would be to replace the others with a decent set of two or three Plössl eyepieces as well. I found both image sharpness and contrast improved noticeably when I swapped my own eyepieces for those supplied.

And the Winner is ...

So are these telescopes any good? The answer is a resounding "yes" for the two traditionally designed instruments. I was surprised at the optical quality of the Swift 864 and Celestron Firstscope 114 EQ. With both properly collimated, the scopes delivered great views of the moon, Jupiter, Saturn, and many deep-sky objects. I also thought they handled magnification well, as evidenced by the sharp views I enjoyed of Jupiter and Saturn at 229x (51x per inch). I am confident new stargazers will be satisfied with either of these as a first telescope.

However, I am less enthusiastic about the Celestron Firstscope 114 Short. Although it performed reasonably well, the others clearly outdid it. My advice would be to spend a little more money and purchase one of the full-size Newtonians. Although they are bit more cumbersome, their superior optics and mountings make up for it.

Celestron Firstscope 114 EQ

1. Spherical aberration about ¼ wave
2. Only telescope to arrive properly collimated
3. Second best on Saturn
4. Good detail on Jupiter, probably best of all
5. Easy mirror cell to adjust (same cell as in other Celestrons)
6. Best overall

Celestron 114 Short

1. Spherical aberration about 2 wave
2. Rough surface
3. Focusing difficult due to coarseness. Same focuser as FS 114 EQ, but auxiliary lens seems to cause coarseness
4. Received with primary mirror out of collimation
5. Saturn: Cassini's Division seen, but vague
6. Jupiter was not as sharp as Swift, Celestron, or Tasco long
7. f/4 primary mirror with 2.25x "auxiliary lens" (aka Barlow)

Swift 864

1. Spherical aberration about ¼ wave
2. Minor astigmatism
3. Received: with the Primary and diagonal mirrors considerably off collimation
4. Mirror was being pinched in cell (same cell as other Taiwanese scopes)
5. Push-pull mirror cell most difficult to adjust, requiring both an Allen wrench and a Phillips screwdriver
6. Largest central obstruction of "normal" scopes
7. Best views of Saturn (Cassini's Division clear in 4mm eyepiece)
8. Good on Jupiter

Phil Harrington's equipment reviews appear often in Astronomy. *His book* Star Ware *is available through bookstores and his website — http//www.philharrington.net.*

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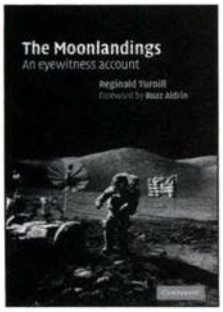

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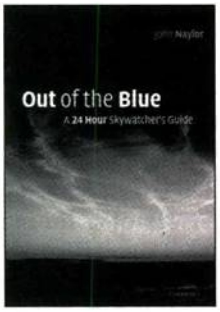

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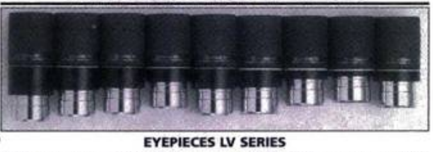

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'Tis the Season to be Shopping

Looking for the perfect gift for the stargazer in your life? Let Astronomy *be your personal shopper.*

by Jeremy McGovern

Seeming to arrive earlier every year, the holiday season is already in full swing. Whether your winter celebration is Christmas, Hanukkah, Kwanza, or Three Kings' Day, gift giving is likely to be involved. And everyone knows how hard that can be. If you have a special astronomer on your list, or if you want to drop a hint for a potential Père Noël, here are some suggestions.

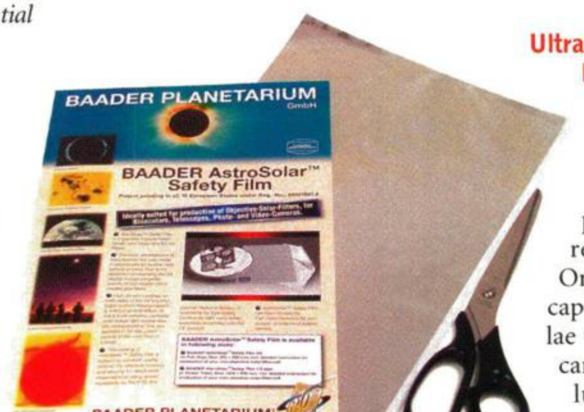
David H. Levy's Guide to the Stars Planisphere

Ken Press, $12.95

For beginning or casual astronomers, a great gift is David Levy's 16-inch Guide to the Stars Planisphere — a circular star chart used to locate constellations regardless of the time of day or season. By rotating two durable plastic disks, the stars will appear in a white oval with the corresponding hour and day notations. This easy-to-read guide was designed by Levy, renowned comet hunter and accomplished astronomer.

David H. Levy's
Guide to the Stars

In addition to the constellation nomenclature, the planisphere provides information on meteor showers, planets, and objects easy to find with binoculars. And with its durable design, the ink won't rub off while using this chart in the field.



Baader AstroSolar Film

Baader Planetarium, $30 – $70, depending on size

Too many solar filters degrade images or are prone to pinholes that allow the sun's intense light to pass through and injure an observer's eyesight. Baader offers AstroSolar, a high-strength safety film that revolutionized the standards of solar filters, serving up brighter, sharper images with more of the sun's natural light. The film comes with easy-to-follow instructions on how to make a filter to fit your recipient's scope. Opening up a world of opportunities for daytime observations, this solar film should become a treasured possession.

ORION
UltraBlock™

UltraBlock Narrowband Light-Pollution Filters

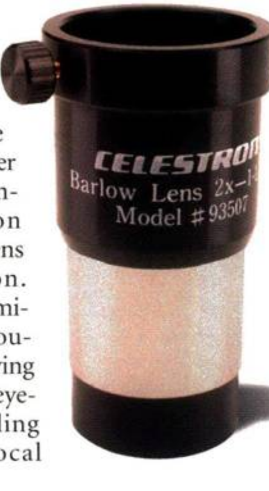
Orion Telescopes and Binoculars, $99.95 – $129, depending on size

Astronomers living in heavily light-polluted areas will be ecstatic to receive an UltraBlock filter from Orion. The filter can help urbanites capture emission and planetary nebulae that are otherwise invisible, and it can even make a difference to those lucky enough to observe in dark skies. It works by blocking wavelengths from artificial lighting, which wideband filters can't stop.

Celestron 1.25" 2x Deluxe Barlow Lens

Celestron, $60

Help your special someone increase his or her observing potential this season with a Barlow lens from Celestron. Easy and economical, this lens doubles the magnifying power of your eyepiece by doubling its effective focal



length. This multicoated, achromatic compact lens mounts on the scope's focuser before the eyepiece. With this addition to an accessory collection, it will be like having two eyepieces in one.

DURACELL
DURACELL

Green Laser Pointer

Beta Electronics, Inc., $189.97

Projecting up to 5,000 feet away, green laser pointers are remarkably brighter than their red counterparts because human eyes are more sensitive to green light. Sky watchers can use the lasers to show off in front of novices by pointing out stars and highlighting constellations. Also, the pointer can assist in aligning a telescope, making it a helpful tool for any backyard astronomer.

Dew Remover System

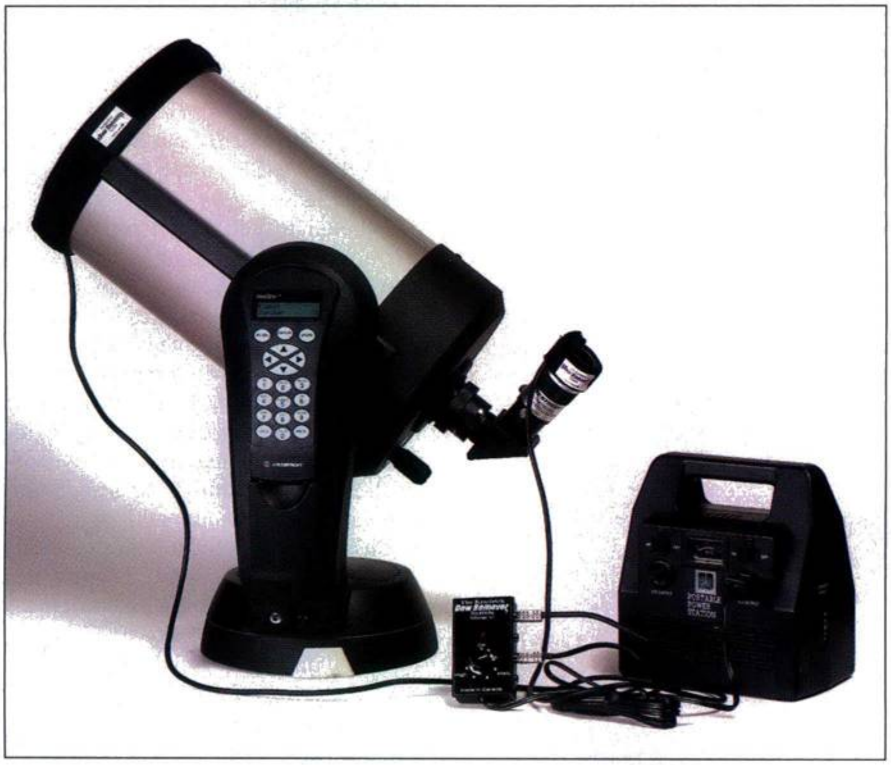
Kendrick Astro Instruments, $75 for controller and $24 – $84 for heater, depending on size

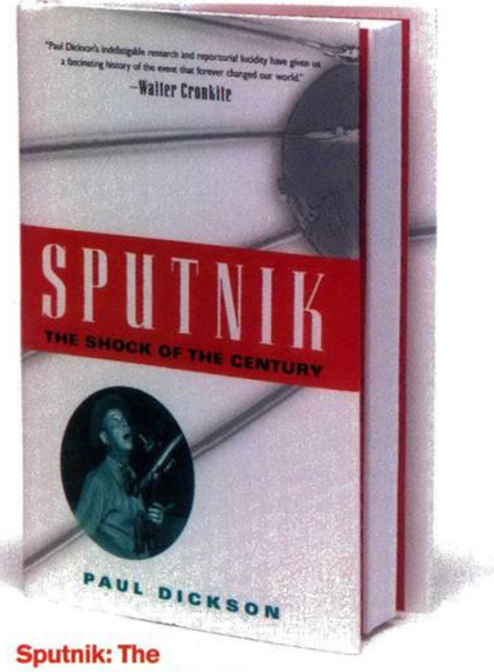
So many obstacles await hobbyists on a night of stargazing. Even if the skies remain clear and light pollution is low, dew formation can frustrate the best-prepared amateur. Arm your observer with a Kendrick Dew Remover, a duo of a controller and heater that combine to prevent moisture condensation. The option of a rechargeable battery or cigarette lighter adapter makes this system a convenient tool no matter where one is observing. It's a perfect gift for anyone living in regions that bring chilly nights along with dew and frost.

Accessory Case (No. 50)

Meade Instruments, $65

Why invest hundreds of dollars in accessories and not properly store your equipment? If you know of anyone who easily misplaces an eyepiece or abuses a filter, give him or her a Meade accessory case this year. Pre-cut foam lines the case and protects precious accessories from accidents, while a locking latch keeps them from growing legs.

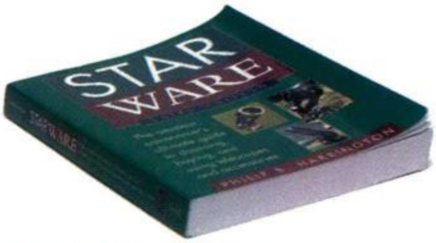



"Paul Dickson's indefatigable research and reportorial lucidity have given us a fascinating history of the event that forever changed our world."
—Walter Cronkite
SPUTNIK
THE SHOCK OF THE CENTURY
PAUL DICKSON

Sputnik: The Shock of the Century

Paul Dickson, 310 pages, Walker and Company, New York, 2001; ISBN 0-8027-1365-3; hardcover, $28.

After the Soviet Union sent the first man-made object into space, myriad books tackled Sputnik and its effects. None have been as successful in analyzing the satellite's launching of the Space Age as Paul Dickson's *Sputnik*. Readers will find frank evaluations of the major players involved and learn about space exploration and the subsequent political landscape in both the United States and the Soviet Union.



Star Ware, Third Edition

Phil Harrington, 422 pages, John Wiley & Sons, New York, 2002; ISBN 0-471-41806-4; paperback, $19.95.

With an astounding assortment of choices, amateur astronomers need more help than ever selecting new telescopes, accessories, or even what to view in the night sky. In its third edition, *Star Ware* by Phil Harrington remains the essential guide for choosing, purchasing, and using telescopes and accessories. This comprehensive handbook helps burgeoning newbies and seasoned veterans alike make informed decisions and reach their full potential. Not only a telescope buyer's guide, the book introduces astrophotography, supplies observing tips, assists in scope maintenance, and challenges readers with do-it-yourself projects. This revised edition stays current with the ever-changing world of amateur astronomy with updated reviews and information. *Star Ware* makes a perfect gift for anyone thinking about investing some holiday largesse into a new scope or accessories.

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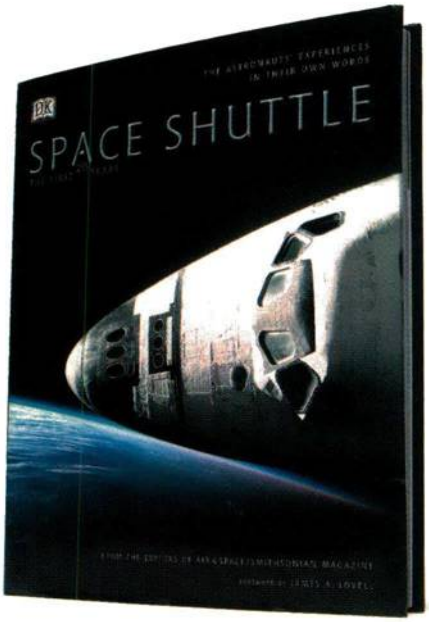


Space Shuttle: The First 20 Years

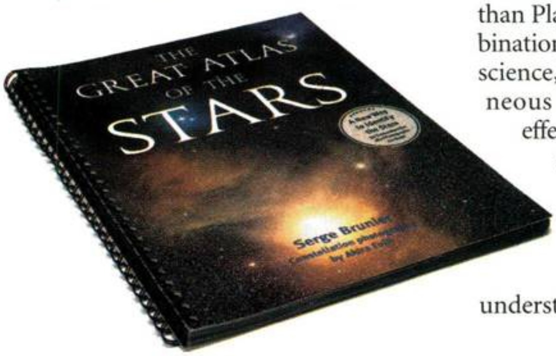
Edited by Tony Reichhardt for Air & Space/Smithsonian Magazine, 320 pages, DK Publishing, New York, 2002; ISBN 0-7894-8425-0; hardcover, $40.

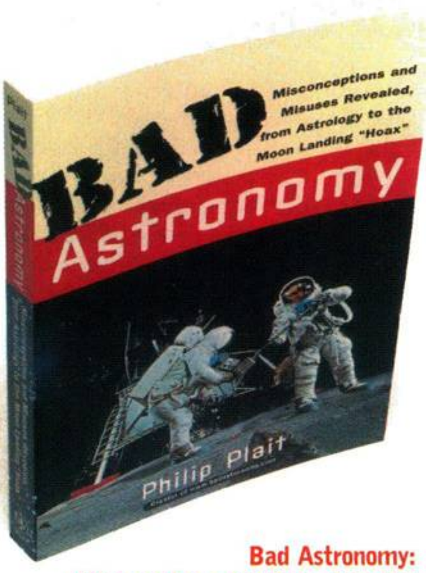
With inspiring, oversized images, coffee-table books make great holiday gifts. For one of the best offerings this season, DK Publishing presents *Space Shuttle: The First 20 Years.* In it, 77 space shuttle astronauts candidly detail stories of life on the space shuttle. Readers receive astronauts' perspectives on training for the launch, rocketing into orbit, adjusting to weightlessness, conducting experiments, and dancing the ballet of spacewalks. Without the resources of Dennis Tito, most of us may never get closer than these pages to the breathtaking views from orbit.

The Great Atlas of the Stars

Serge Brunier; Akira Fujii, photographer; 112 pages, Firefly Books, Toronto, 2001; ISBN 1-5520-9610-6; spiral bound, $49.95.

The team of journalist Serge Brunier and astrophotographer Akira Fujii has armed backyard astronomers with a helpful tool in constellation identification with *The Great Atlas of the Stars.* This book not only examines 30 of the 88 constellations, but also details the major stars, nebulae, and galaxies in each. Many of Fujii's photographs of the night sky are overlaid with a clear sheet marked with the stars' names and dot-to-dot diagrams to illustrate constellation shapes. Though not ideal as a field guide due to its size, it allows for some splendid color spreads of celestial objects, such as the Large Magellanic Cloud, the Orion Nebula, and Omega Centauri. If you plan on giving this gift, make sure the recipient lives in the Northern Hemisphere — Brunier and Fujii focus on constellations visible only from that vantage point.

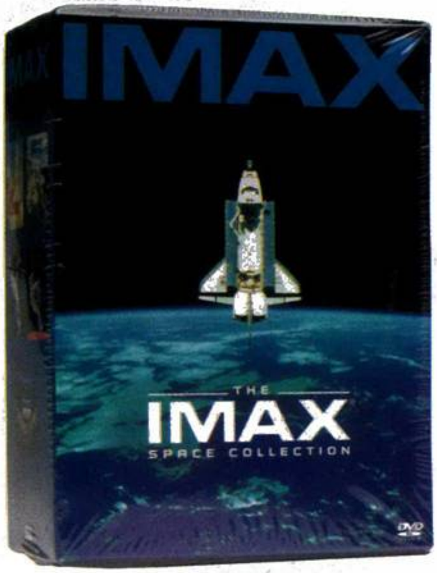



BAD Astronomy
Misconceptions and Misuses Revealed, from Astrology to the Moon Landing "Hoax"
Philip Plait

Bad Astronomy: Misconceptions and Misuses Revealed, from Astrology to the Moon Landing "Hoax"

Phil Plait, 288 pages, John Wiley & Sons, New York, 2002; ISBN 0-471-40976-6; paperback, $15.95

Who better to pen *Bad Astronomy*, the first book in Wiley's *Bad Science* series, than Phil Plait? The Sonoma State University astronomer operates badastronomy.com, a website devoted to debunking myths, legends, and conspiracies that abound in astronomy. In this spirit comes a hard copy more expansive and in-depth than Plait's online presence. With a combination of wit, skillful writing, and good science, *Bad Astronomy* addresses erroneous beliefs, including the Coriolis effect in home washrooms, and clears up age-old questions such as, "Why is the sky blue?" After dissecting and destroying misconceptions and hoaxes, Plait presents the truth in an easy-to-understand and entertaining format.



DVD collections have distinct advantages over their VHS counterparts. For one thing, DVD sets hold more and take up less space than cassettes. For another, many DVD collections include special bonuses, such as behind-the-scenes views, alternate endings, and other features to keep fans entertained. Here are a few suggestions for the space cadet on your list.

The IMAX Space Collection

Warner Home Video, 2001, $74.95

With some of the finest video ever shot of Earth from space, the *Imax Space Collection* will astound and amaze. This five-DVD collection contains the IMAX films *Hail Columbia!* (1982), *The Dream Is Alive* (1985), *Blue Planet* (1990), *Destiny in Space* (1994), and *Mission to Mir* (1997). With outstanding shots and dynamic sound, this boxed set takes viewers on a trip down memory lane, recollecting moments from the last 20 years of space exploration. Stunning footage will reinvigorate dormant dreams of becoming an astronaut and make a perfect addition to any DVD collection.

THE NEXT GENERATION
TNG 2

Star Trek: The Next Generation

Paramount Home Video, 2002, $99.99 per season

Paramount Home Video has some of the most popular DVD releases of the year with the complete series of *Star Trek: The Next Generation*. Released periodically since early 2002, all seven seasons (1987–1994) will be available to the public by December 31. Each box contains digitally remastered episodes from a particular season, as well as anecdotes from cast members, analyses of character and plot growth, and production notes. With 26 episodes and special bonuses in each set, backyard astronomers who happen to be Trekkies have the perfect alternative to observing when Mother Nature isn't cooperative.

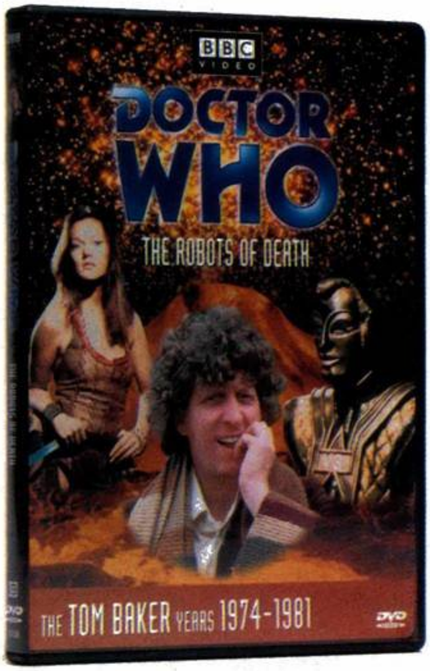
BBC Sci-Fi and Science Series

BBC Video, 2002, $19.98 – $27.98

Not to be outdone, the BBC offers DVDs sure to please space-lovers. Most notable is the complete *Dr. Who* series. Hardcore fans love to argue over which actor best portrayed the time traveler, but whether you fancy Tom Baker or another incarnation, you'll find what you're looking for in this collection. Each disk features a photo gallery, cast commentary, trailer, and pop-up production notes.

Don't panic! Douglas Adams' cult classic is now on DVD. *The Hitchhiker's Guide to the Galaxy*, a six-part series that originally aired in 1981, is adapted from the best-selling book ever published by the corporations of Ursa Minor. Along with the galactic adventures of Arthur Dent, the DVD extras include the making of the series, deleted scenes, the original trailer, outtakes, a profile of the late Douglas Adams, and many other gems.

Though not featuring Dr. Who or Ford Perfect, *Hyperspace* makes a great gift idea for any astronomer. It originally aired on the cable network TLC in 2002. In it, Sam Neil takes viewers on an astounding voyage exploring the wonders of our universe. With state-of-the-art computer graphics and tremendous accompanying sound, this three-hour DVD tackles fascinating topics, including star formation, black holes, interstellar travel, and cataclysmic asteroid impacts on Earth.



BBC VIDEO
douglas adams
the hitchhiker's guide to the galaxy
DON'T PANIC!
42

For those without DVD players, the BBC sells VHS-formatted versions of these titles and others, including *Red Dwarf* and *Blake's 7*.

Now that you are armed with a few ideas, all that's left is to decide what best suits your astronomer — or yourself. The featured books and DVDs should be easy to locate at any bookstore or electronics boutique; however, if you have trouble tracking down any of the other products, the information on the previous page will help you contact manufacturers or distributors directly. ■

Jeremy McGovern, Astronomy.com*'s editorial assistant, hopes to get many presents this year.*

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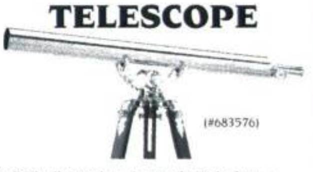

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Beginner's sky

Cosmic adventures for the neophyte astronomer. By Glenn Chaple

"Beginner's Sky" was the brainchild of Jerry Burstein, who wanted a column for new stargazers that would entertain as well as inform. Thanks, Jerry, for inspiring us to get outside, marvel at the sky, and learn what lies above. May you and your Sidekick enjoy a lifetime of exciting cosmic adventures!

Now that Jerry has passed the baton to me, I hope to continue his mission. I've been an astronomy fanatic since the Sputnik era of the 1950s. I remember sitting wide-eyed as my grade-school teacher described the sun, moon, planets, and distant stars. I rushed home and badgered my parents to buy me a small telescope. They did, and what followed was a fate that befalls many a beginner. I didn't know the night sky well enough to locate appropriate targets for my little scope. Frustrated, I gave up.

I got a second chance at astronomy a few years later, when my friend Ray Gerbi invited me to join him in a casual observing session. On that late summer evening in 1963, Ray pointed out major stars and constellations, then showed me telescopic views of Saturn, a double star (Mizar), the globular cluster M13, and the galaxy M31. I was hooked for life.

> *"Meteor showers are nature's way of rewarding us for taking the time to go outside and admire the night sky."*

In the four decades since, I have spent hundreds of hours viewing thousands of sky objects, from meteors in our own atmosphere to quasars billions of light-years away. I love sharing my experiences with newcomers young and old (I teach middle-school science, as well as adult-ed courses in astronomy). But in some ways, I'm a beginner, too. Innovations in telescope technology and a vast, beckoning list of sky objects yet to explore constantly remind me there's always more to learn. Astronomy is truly a lifetime pursuit.

This month, the astronomical world is abuzz over the return of an annual meteor shower called the Leonids. Shooting stars only in name, meteors are actually cast-off bits of rock from a comet as it wends its way around the sun. When Earth passes through this trail of debris on its own orbit, thousands of these tiny fragments (usually no larger than a pea) plummet into the atmosphere. At speeds of 20 to 60 kilometers per second, these flecks of comet dust burn up to produce the meteor showers we know and love.

Meteor showers appear to streak outward from a point in the sky called the radiant (the Leonids' radiant is in — you guessed it — the constellation Leo the Lion). But in reality, the particles that produce a meteor shower are traveling parallel paths (you experience this illusion when standing on parallel railroad tracks that seem to converge in the distance).

I think meteor showers are nature's way of rewarding us for taking the time to go outside and admire the night sky. Last year's display was fantastic — the best meteor shower I've ever seen. I tiptoed outside at about 3 A.M., gazed into the southeast sky, and within seconds saw a Leonid. In less than a minute, another zipped across the sky, then another — sometimes two at a time. And so it went until dawn ended the show.

What's in store this month? No one knows for sure. Most years, you'd have to wait a full hour just to see a half-dozen Leonid meteors. But the dust trail was built up by parent Comet Tempel-Tuttle on a 1998 swing by the sun (a full orbit takes about 33 years). Also, this month we're intercepting two thicker streams of debris left over from the comet's passes in 1767 and 1866, so we should see more meteors than usual. Back in 1966, Leonids fell at a rate of 100,000 per hour. That's not a meteor shower — that's a storm. Although we haven't seen that kind of activity since the comet's most recent pass, forecasters predict an impressive tempest this year. The only thing to do is to wait and watch.

Astronomers can't predict exactly how many Leonid meteors we'll see, and they can't pinpoint when peak activity will occur. My strategy will be to go outside between 2 and 3 A.M. on the mornings of November 18 and 19. As I did last year, I'll dress warmly and pick an area in my backyard that offers a wide-open view of the southeast sky. A bright moon will hide faint meteors from view, but there should be plenty of brilliant Leonids to overcome the moonlight. I'll wait and watch.

Observing meteor showers is fun and relaxing for beginners and experts alike. If you decide to watch this year's Leonids, follow Jerry Burstein's example and invite along a Sidekick. Astronomy is great when shared with someone special.

Like Jerry, I welcome your questions and comments. Contact me at gchaple@astronomy.com. Clear Skies!

Target Leonids

1998 Leonid shower; John Chumack

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Beginner's helpful tips

Reading treasure maps of the night sky. By Andrew Fazekas

At first glance, star charts may look like confusing webs of lines and dots, knots of mysterious acronyms and technical jargon. New stargazers who turn to them for help navigating the heavens may feel even more befuddled. But don't give up. Star charts are like encoded treasure maps — they guide you to hidden riches of the night sky, pointing out thousands of celestial jewels. The trick is knowing how to decipher them.

X Marks the Spot

It's important to understand how astronomers pinpoint the positions of stars in the sky. From our earthbound perspective, stars appear to swirl in an arc from east to west every night. It's actually Earth that's spinning, but astronomers find that imagining the stars painted on the inside of a giant sphere — as the ancients did — is still a handy model. In this idealized system, Earth sits stationary at the center of a huge rotating globe called the celestial sphere.

Our planet's familiar coordinate system is projected onto this globe. So Earth's axis, extended to infinity, is the axis of the celestial sphere, and the North Star, Polaris, marks the North Celestial Pole. In the sky, latitude is called declination, while longitude goes by right ascension. Declination (abbreviated Dec.) is measured in degrees, minutes, and seconds starting from 0° at the celestial equator to 90° at the poles. Declinations north of the equator are positive; those south of the equator are negative. Right ascension (R.A.) is measured in hours, minutes, and seconds where an Earth-day of 24 hours marks a full rotation of 360°. The baseline of 0h R.A. is the point on the celestial equator where the sun is found on the first day of spring in the Northern Hemisphere.

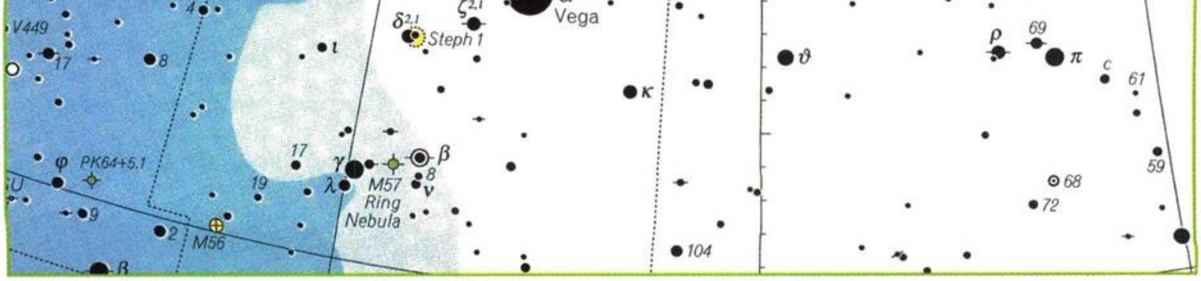
Time plays a crucial role in how star charts are organized. Celestial coordinates change as Earth's orientation shifts (like a toy top, our axis traces a slow circle in space due to the gravitational tug of the sun and moon, so in 10,000 years, the North Star will be Vega). Also, because Earth rotates on a tilted axis as it orbits the sun, our celestial vista depends on the time of night, our own latitude, and the date. Atlases include all of this information.

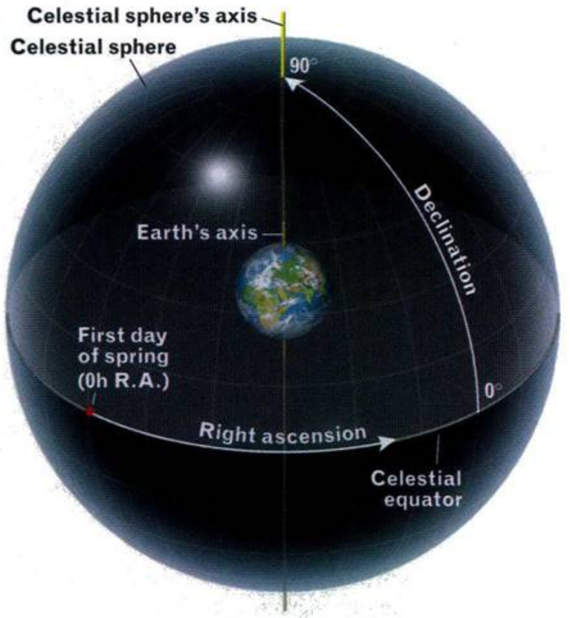
Choosing the Right Map

The level of detail varies by star chart. At the lower end, maps of the sky may show only the brighter stars and constellations — ideal for new stargazers. Star charts that include objects visible through binoculars or telescopes are more crowded and may be a bit confusing at first, but by taking note of only the brightest stars, readers can still pick out familiar constellations. Wil Tirion's *Sky Atlas 2000.0*, for instance, contains more than 40,000 stars, while *Uranometria 2000.0* plots an astounding 280,000. The main reason for this difference is how brightly the star shines.

The brightness of a celestial object is represented by its diameter on the chart — bright objects are large circles, while faint ones are mere specks. Each dot size represents a particular magnitude, a measure of bril-

Star charts may differ by scale and scope. The *Cambridge Star Atlas, Third Edition*, below, provides a broad overview of the sky around the star Vega. Reprinted with permission from Cambridge University Press





Celestial objects have extraterrestrial addresses given by right ascension and declination (analogous to longitude and latitude, respectively). These are plotted on an imaginary "celestial sphere" that surrounds Earth. *Astronomy:* Elisabeth Rowan

liance first proposed by the Greek astronomer Hipparchus around 150 B.C. In this system, bright objects have smaller magnitudes than dim ones (the full moon shines at –12.7, while M31, the harder-to-see Andromeda Galaxy, glows at 4.5). The *Cambridge Star Atlas* plots objects as faint as the naked eye can see in dark skies (about 6th magnitude), while *Uranometria 2000.0* displays objects at the limit of today's popular 7x50 binoculars (9th magnitude).

What's in a Name?

All 88 constellations are clearly outlined in major atlases, while their constituent stars can be identified in a bewildering number of ways. (Vega, the fourth-brightest star in the sky, has more than 40 names!) Some stars may have popular monikers. Others go simply by Greek letters according to brightness — this naming system, known as Bayer, dates to 1603 (Vega, the brightest star in the constellation Lyra, is Alpha Lyrae). The Flamsteed system numbers the stars of a constellation from west to east (Vega is 3 Lyrae). Other classification systems include the *Bright Star Catalog* (known as HR for "Harvard Revised"), which inventories 9,000 naked-eye stars, and the *Henry Draper (HD) Memorial Catalog*, which lists the spectral classes of 300,000 stars.

Star clusters, nebulae, and galaxies are mainly identified by either their number in the Messier catalog (M) or their designation in the more extensive *New General Catalogue* (NGC) and its extension, the *Index Catalogue* (IC). These deep-sky objects may appear in atlases as ovals, circles with cross-hairs, or squares.

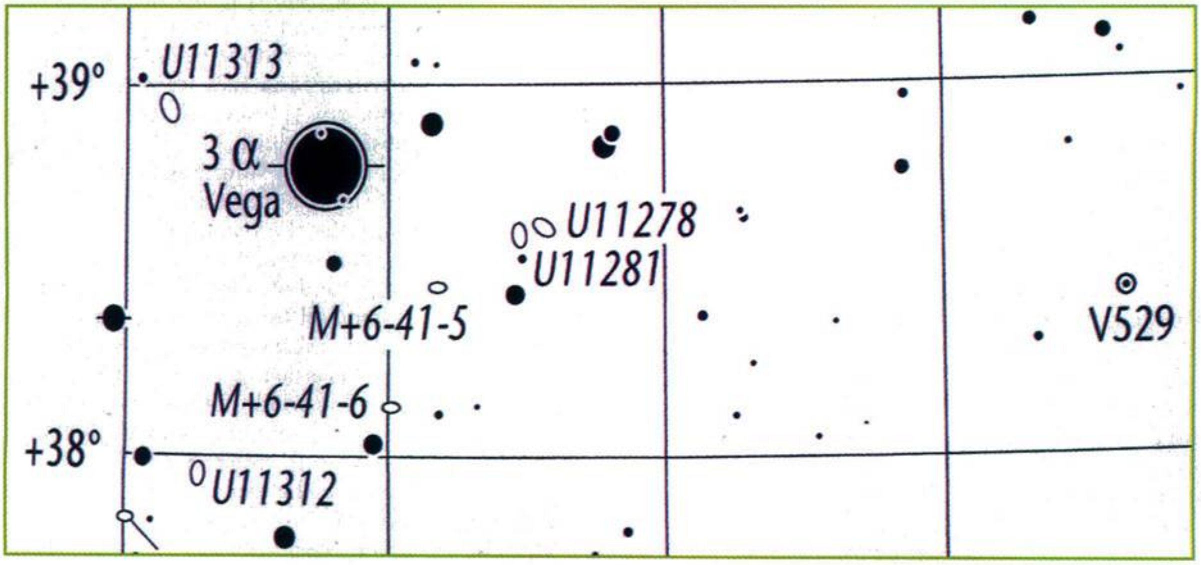
Recommendations

Once you've explored the naked-eye objects found in the most basic charts, it's time to upgrade to a more complete star atlas. With a comfortable limiting magnitude of 6.5 and a manageable 9,500 stars, The *Cambridge Star Atlas* is great for showing neophytes the constellations, well-known double stars, and clusters. *Star Atlas 2000.0* offers more of a challenge with an 8.1-magnitude limit and more than four times the stars, along with 2,500 deep-sky objects. Neither shows everything visible through a small- or medium-sized scope. For that, you need *Uranometria 2000.0*, with its fainter 9.5-magnitude limit, hundreds of thousands of stars, and over 10,000 deep-sky objects.

As you become more comfortable cruising the constellations and locating ever-fainter deep-sky challenges, star atlases will help you plot a course to your next celestial treasure. ■

Andrew Fazekas is an astronomy columnist and conducts stargazing workshops in Montreal.

***Uranometria 2000.0*, below, zooms in on a smaller area than the *Cambridge Star Atlas*, and it plots fainter objects so it is more detailed.** Reprinted with permission from Willmann-Bell, Inc.; copyright 1987–2001



Exploring the Depths of Andromeda

By David Higgins

The great spiral galaxy M31 in Andromeda is probably the most talked about deep-sky object in both amateur and professional astronomy. Over the years, volumes have been written about this celestial wonder.

The great Persian astronomer Abd al-Rahman Al-Sufi first mentioned M31 in his *Book of the Fixed Stars* in 964 A.D., in which he referred to it as Andromeda's "little cloud." Al-Sufi gives a pretty good description of what this great galaxy looks like with the naked eye. But even today under the light pollution and haze associated with populated areas, most urban observers can still glimpse M31.

M31 has been pivotal in understanding the nature of galaxies and the universe as a whole. The belief that distant spiral galaxies like M31 were actually spiral nebulae in the process of forming solar systems — and part of our own galaxy — was well entrenched in astronomical thought in the early 1900s. But then astronomer Vesto M. Slipher made a discovery in 1912 that would soon unravel the truth about such "spiral nebulae." Slipher realized that they were receding from Earth at amazing speeds, suggesting that these supposed nebulae were moving at extremely large distances. At the time these distances were not yet known so it was difficult for most astronomers to believe the spiral nebulae were, in reality, galaxies just like our own Milky Way.

Enter Edwin Hubble. His 1923 photographs of M31 and the subsequent discovery of Cepheid variables within M31 ended the notion that the spiral nebulae were solar systems in the making. The light curves of Cepheid variables had been determined some years before and had been used by Harlow Shapley to determine the distances of our galaxy's globular clusters, which, in turn, gave researchers a rough outline of the Milky Way Galaxy.

By assuming that all Cepheids, regardless of where they are found, obey the same period-luminosity law, it was not difficult to determine the distance to M31. To say that Hubble's findings caused uproar would be an understatement. Most astronomers understood the significance of Hubble's findings right away, but it took almost ten years for the astronomical community to agree that the supposed spiral nebulae were galaxies, and that the universe was expanding and filled with countless numbers of galaxies.

Besides being one of the most studied objects in the sky, M31 is probably the most photographed deep-sky object as well. And for good reason: M31 is the largest member of the Local Group of galaxies, and at only 2.2 million light-years away it is a huge galaxy even in finder scopes. The Local Group, including our own Milky Way, holds over 30 galaxies that interact with one another. This galactic grouping is important to astronomers because it provides an easier and more accessible way to study different types of galaxies. The Local Group also provides examples that help in understanding the nature of our own Milky Way Galaxy.

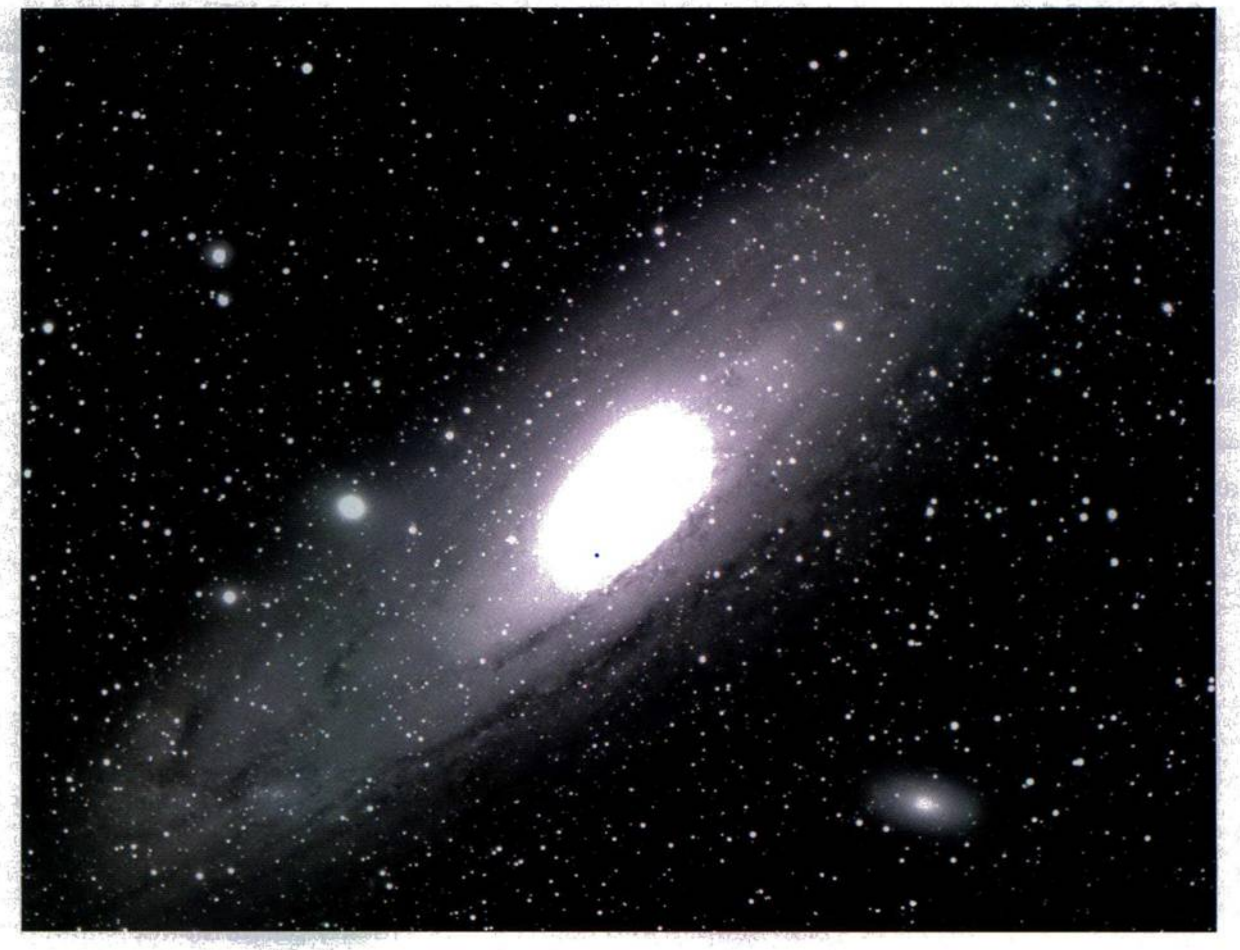
Our own galaxy and M31 are alike in many ways. They are both large spiral galaxies. They both contain gas and dust clouds, stellar associations, HII regions, and open clusters, as well as a system of globular clusters. In fact, M31's globular cluster system is so much like our own that these distant globulars give astronomers the opportunity to observe and test theories about the creation of the Milky Way.

The globular clusters of M31 are what astronomers call metal poor, meaning they contain a very low ratio of heavy elements to hydrogen in their stars. This is due in part to the way the clusters orbit about the galactic center, occasionally plunging through the disk of M31. This sweeps out the dust and gas of the cluster, leaving it in the disk of M31 and stripping the globular clusters of heavy metals.

I enjoy observing globulars, whether they're the large showy clusters of the Messier or NGC catalogs, or the more exotic versions, such as the Palomar or Terzan globular clusters. But one of my favorite activities is the search for extragalactic globular clusters, those that belong to other galaxies such as M31. Because M31 is so large and close, it presents lots of detail to the careful observer, including the large globular cluster system. You won't find any of these globulars plotted on any of the popular star charts or atlases. As with any journey you will need a map, something that will give you some idea of where you're going and how to get there.

What you really need is the great guide to Andromeda published by Paul Hodge, an astronomer at the University of Washington and editor of the *Astronomical Journal.* Hodge's *Atlas of the Andromeda Galaxy* is nothing short of a Rosetta Stone in the search for M31's globulars. This atlas contains 41 large-scale charts of M31 and plots 355 globular clusters, giving the observer an easy-to-read sky map. In addition to globular clusters, Hodge's atlas also lists 413 open clusters, 188 stellar associations, and 730 dust clouds.

The following list of globular clusters and their descriptions are simple in nature because all the clusters look like stars through amateur telescopes. They were observed with a 24-inch f/4 Newtonian and a 9mm Nagler eyepiece, providing a magnification of 270x. Don't let the magnitudes of these clusters dissuade you from trying your hand at tracking them down; some will be easy and some will require averted vision and a steady sky. In certain cases, you might not find any at all. But isn't that what amateur astronomy is about — the desire to learn about the universe and the challenge of pushing our equipment and ourselves to the limit? What a hobby! ■



Jim Edlin and Steve Leikind took this CCD image of M31 with a 5-inch f/5 Takahashi reflector on an AP 900 Astro-Physics mount and an ST-10 CCD camera. The image is a mosaic of two images that cover M31, M32, and NGC 205 as well as two additional images taken to make it rectangular. The area covered by the entire mosaic is approximately 2° by 1°. The image contains a staggering number of deep-sky objects.

G35—Magnitude 15.6, size 2.9"
Very faint with averted vision required for best view.

G78—Magnitude 14.3, size 3.2"
Bright and easily seen with direct vision.

G87—Magnitude 15.6, size 2.9"
Very faint with averted vision required for best view.

G96—Magnitude 15.5, size 2.7"
Faint but seen with direct vision.

G119—Magnitude 15, size 2.7"
Faint but seen with direct vision.

G124—Magnitude 15.7, size 2.3"
Very faint with averted vision required.

G150—Magnitude 15.4, size 2.7"
Very faint with averted vision required. In same eyepiece field with g124.

G156—Magnitude 15.6, size 2.5"
Faint with averted vision required for best view.

G172—Magnitude 15.2, size 2.4"
Very faint with averted vision required.

G226—Magnitude 15.5, size 3.8"
Faint with averted vision required. In the same eyepiece field with G244.

G233—Magnitude 15.4, size 2.6"
Faint and difficult with averted vision required.

G244—Magnitude 15.4, size 2.6"
Faint but seen with direct vision.

G263—Magnitude 15.5, size 2.5"
Faint with averted vision required.

G73—Magnitude 15, size unknown
Faint but seen with direct vision. (This globular is included although it is not associated with M31. It is a globular in M31's companion galaxy NGC 205.)

The descriptions given are varied because some globular clusters with the same magnitude are easier to see than others, a consequence of having to look through the gas and dust of our Milky Way as well as through that of M31. Try to visually track down some of these clusters with as large a telescope as possible and you won't be disappointed. In addition to the visual, give CCD imaging a try. Attempt a combination of disciplines and you'll be amazed at what you'll find.

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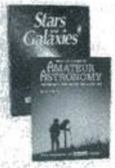

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11 GPS
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Celestron's 11" go-to GPS scope – the **NexStar 11 GPS** – got a *rave* review in *Sky & Telescope*. The review gave it "an enthusiastic two thumbs up and a gold star." They said it has "brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

Multicoated optics are standard with the NexStar 11 GPS (other brands charge extra). We have the NexStar 11 in stock (31 as this was written). Call us and you can be observing with yours in about a week.

Time's running out for the $500 rebate on the multicoated NexStar 8 GPS!

NexStar 8 GPS
$1999 after rebate

The in-stock 8" **Celestron NexStar 8 GPS** (22 on hand as this was written) has Starbright multicoated optics for brighter images *at no extra cost.* Other brands charge extra for multicoated optics.

SBIG ST-237A CCD owners can convert the NexStar's unique Fastar optics to a super fast f/1.9 focal ratio for wide field CCD imaging. Of all GPS scopes, *only Celestron NexStars have multicoated Fastar optics!*

Add the $500 cash rebate available direct from Celestron on any NexStar 8 GPS bought before October 31, and you've got one very hot deal! For details, see our website at **www.astronomics.com**.

The new Celestron Modular i Series 8" GPS SCTs starts at only $1199!

NexStar
8i
$1199
shown with optional tripod and computer
CELESTRON

If you compare, you'll see that the new **Celestron NexStar 8i** go-to costs less than comparably-equipped competitive 8" scopes. Starting at only $1199 for a complete working tabletop scope (not even available from the competition), you can add the options that you, and your budget, feel comfortable with. An *iCOMP* computer hand control with 40,000 deep space objects in memory is $149. A light weight travel tripod is $149. A heavy duty tripod (same as the NexStar 11 GPS) is $299. If you want the convenience of GPS auto-alignment, add it for only $199. However you outfit your NexStar 8i, it's enough scope to keep you observing for the rest of your life, at prices that leave competitive scopes behind.

A 5" GPS-ready scope starts at $899!

The **Celestron NexStar 5i** is the first 5" telescope to have a fully automatic GPS go-to computer available as an option. No other 5" scope has a GPS system! Even better, the modular nature of the NexStar 5i means that you can build up to a fully automatic GPS system gradually, starting at only $899 for a complete working tabletop scope. And multicoated optics are standard equipment with the NexStar 5i, not an extra-cost option as with other brands. NASA uses 5" Celestron multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium images?

Sell your used telescopes and accessories quickly by using the classified ads you can run *for free* at www.astrofieds.com

The Stellarvue refractor is a "hot new product."

AT1010A $499.95
shown w/optional diagonal and

The 80mm f/6 **Stellarvue AT1010** achromatic refractor was named a "Hot New Product of 2001" in the December 2001 issue of *Sky & Telescope*. Even better, independent user reviews say it competes favorably with ED semi-apochromatic telescopes that cost twice its modest price, and that it easily outperforms imported achromatic scopes in color correction and resolution. The AT1010A has hand-assembled and triple tested optics, tube rings, tripod adapter, 2" focuser with both 1.25" adapter and T-threads, red dot finder, oversize rubberized focus knobs for easier use in cold weather, and a soft padded carry case. It's a super deal and it's in stock to ship now.

Discovery Dobsonian reflectors start at only $339.

Why settle for an imported Dob when you can have made-in-the-USA quality *for less money!* Discovery doesn't use imported, mass-produced optics that are merely spot-checked to see if they're acceptable. Discovery optics are made in California by optical craftsmen, one quality mirror at a time. Each is hand figured to diffraction-limited performance, and it doesn't leave the Discovery optical shop until it's right.

Each DHQ series Dob has an adjustable metal primary mirror cell, a true *thin vane* adjustable 4-vane diagonal mirror spider, *two* Plössl eyepieces, a built-in tube balancing system, a tube carry handle, new oversized bearings, a 6 x 30mm finder, and a dust cover. You can get an upgrade kit that adds two more Plössl eyepieces, an eyepiece rack, a second dust cover, and a Moon filter for only $49 more!

Premium Dobs from 10" to 17.5" in aperture are also available. And for those who need big aperture portability, truss-tube Dobs are available in apertures from 12" to 24". Here are the Discovery 6" to 10" DHQ Dob prices:

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6" f/8 Discovery DHQ	$\$339^{00}$, plus $49 freight
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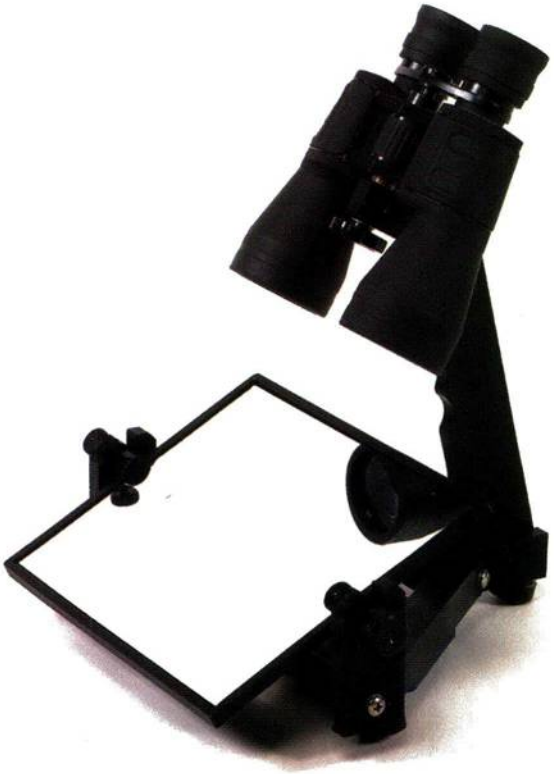
STAR STUFF

PRODUCTS

Look *Down* on the Stars with Sky Window

Binoculars are the TV dinners of the observer's larder. Quick to pack and easy to carry, they're perfect for those nights when preparing a full spread — eyepieces, telescope, and other gear — seems like too much hassle. But in some ways they're not as satisfying, a fact that becomes apparent when you notice how shaky the view looks, or how sore your neck feels the next day. Sky Window from Trico Machine Products aims to change all that. The setup evokes a microscope — a light, anodized aluminum mount stably supports your binoculars, which point down toward a mirror that tilts back and forth. The Sky Window provides wobble-free views of the stars and can be attached to a tripod or set on a flat surface (its rubber feet come with plastic caps for easier swiveling). A laser bracket for use as a finder is sold separately for $22.50.

$229.95. Trico Machine Products, 5081 Corbin Drive, Bedford Heights, OH 44128; (216) 662-4194; website, www.tricomachine.com/skywindow.



BOOKS

Our Cosmic Origins: From the Big Bang to the Emergence of Life and Intelligence

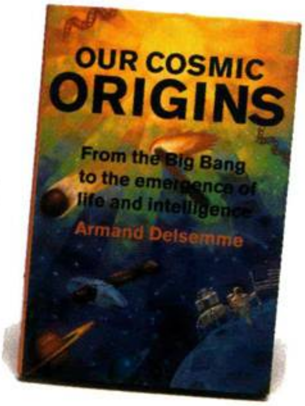
Armand Delsemme, 322 pages, Cambridge University Press, New York, 2000; ISBN 0-521-79480-3; softcover, $15.

Our Cosmic Origins is an unusual mixture of astronomy, biology, cultural theory, and philosophy. Weaving through history from the universe's fiery birth to its nebulous finale, author Armand Delsemme, an astrophysics professor at the University of Toledo in Ohio, poses provocative questions: Why are we here and where are we going? Did time exist before the instant of creation? Does evolution dictate that only the fittest will survive? Are there parallel universes we cannot detect? Finding all these diverse topics in a single, coherent volume was a pleasant surprise.

Unfortunately, the information is slightly out of date. For example, Delsemme believes the emergence of life elsewhere in the universe is highly probable, but he uses a controversial martian meteorite found in Antarctica as supporting evidence. In 1996, NASA announced the seeming discovery of fossilized bacteria in this chunk of rock blasted here from the Red Planet thousands of years ago. Many scientists quickly challenged NASA's hasty conclusion, and the issue is hotly debated to this day.

Nevertheless, *Our Cosmic Origins* is a good read. Delsemme traces evolution from the Big Bang to the gas disks that flattened into galaxies, stars, and planets, to the conglomeration of comets that bombarded the inner solar system and provided us with the very air we breathe.

From there, Delsemme shifts to biology. He details the chemical processes that ultimately led to life and describes how evolution naturally selects the easiest path to progress. Did you know the eye originally developed as a photoreceptive organ for early life forms to obtain energy? It later changed its purpose in animals, gathering light not as a source of nourishment, but as a source of information to feed the brain to increase the chance for survival. Literally food for thought, that bit of evolutionary magic was an important step toward developing the neural networks necessary for higher intelligence.



Delsemme then dives into murkier waters, puzzling over institutions such as religion and politics. Will western democracies that value individuals' rights win the struggle with repressive regimes? He sees these battles as yet another form of evolution and predicts the fittest and strongest will succeed, never presuming to know just who those might be.

But he argues that evolution does not simply happen to us. After criticizing such man-made problems as pollution, Delsemme says *Homo sapiens* can exercise some control over its fate. He writes, "For the first time in the history of life, our intelligence has given us the possibility of influencing the distant future by deliberate choices. We can even choose to survive much longer than eight or ten million years, which is the average survival time of an animal species." The final outcome, he says, is up to us.

— Nick Nichols recently retired as the news media relations manager at the Idaho National Engineering and Environmental Laboratory in Idaho Falls.

Mission Jupiter: The Spectacular Journey of the Galileo Spacecraft

Daniel Fischer, 286 pages, Copernicus Books, New York, 2001; ISBN 0-387-98764-9; hardcover, $32.

Originally published in German in 1998, this book provides an account of the history and highlights of the Galileo spacecraft's exploration of Jupiter and its satellites. Aside from some copyediting glitches ("Pluto" becomes "Plato," for example) and a slight overemphasis on Germany's involvement in the mission, it is up to date, even containing results from the Cassini flyby of December 2000.

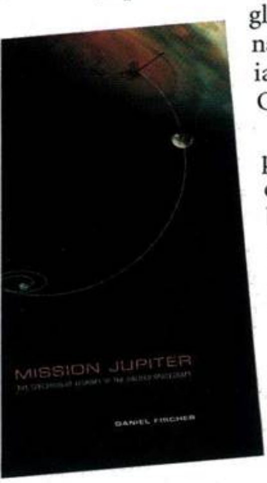
The first chapter reviews the precursor flyby missions of Pioneers 10 and 11 and Voyagers 1 and 2. Then it provides an overview of the tortuous route taken by the Galileo mission from conception in

1976 (as the Jupiter Orbiter Probe) to its launch from the space shuttle Atlantis in October 1989. This path included a few false starts, near-cancellation, problems with one of its rockets, the Challenger disaster (Galileo was scheduled for the next launch), and courtroom challenges over the launch of the plutonium used by the spacecraft for power.

The journey to Jupiter was nearly as complex as the pre-launch gyrations, with the Galileo spacecraft sent careening like a pinball for six years around the solar system, using several gravity assists from Venus and Earth in order to save enough fuel to accomplish its mission. Chapter 2 focuses on the discoveries made along the way, including an experiment to detect life on Earth led by Carl Sagan, the first asteroid flybys (of Gaspra and Ida), and the only direct look at the impact of Shoemaker-Levy 9 on Jupiter. Also recounted is the sad failure of the high-gain antenna.

Chapter 3 recaps the last four centuries of Jupiter research, then covers Galileo's descent into one of the driest regions on its destination planet.

The real meat of the book, however, is in Chapter 4, which covers the main results of research into the atmospheres of Jupiter and four of its moons, first glimpsed by the orbiter's namesake, the great Italian astronomer Galileo Galilei.



Particular attention is paid to Europa, the moon of most interest to astrobiologists, since a global ocean might lie beneath its icy crust. Throughout this chapter, progress reports update the original edition with the latest news.

The book ends with a look to the future. After sustaining crippling doses of radiation from Jupiter's giant Van Allen belts, Galileo will be deliberately crashed into the planet in the summer of 2003.

Future missions may include an Orbiter mission to Europa or even submarines to explore alien oceans. However, apart from Cassini, none are likely to be as grand in scope as Galileo. Fischer's book provides a fitting tribute to one of NASA's greatest accomplishments. — *Randy Gladstone is a planetary scientist at the Southwest Research Institute in San Antonio, Texas.*

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The Webweaver Picks

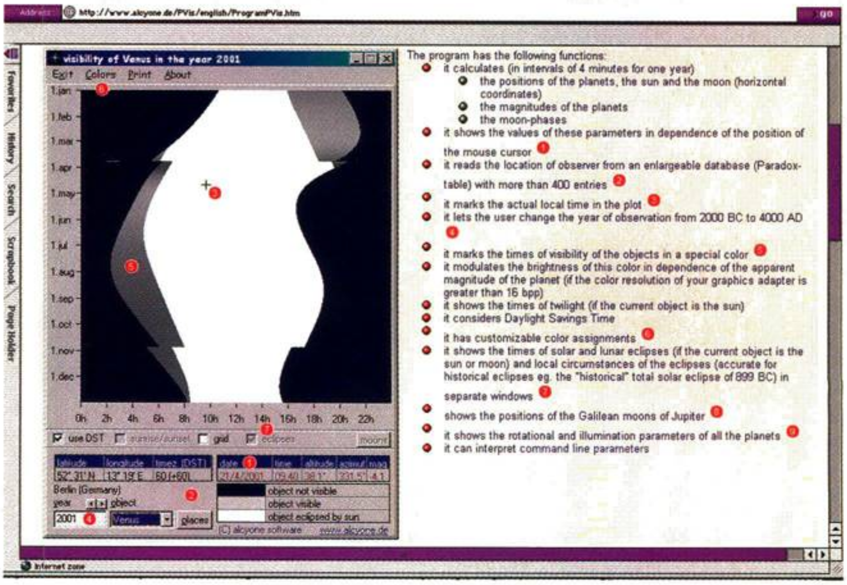
by Richard J. Bartlett

Most astronomers use planetarium software to visualize the night sky. But what if you want more than pretty pictures of the heavens? What if you crave hard data — tables of information about the sun, moon, and planets — for a specific day or even for a whole year? That's the kind of material you might need to produce a club newsletter, and not all planetarium software provides it. An almanac or an ephemeris, a tabular statement of the locations of celestial bodies, is what you require. Fortunately, some programs provide these details and can be found online for little or no money.

Since I have access only to PCs, the following programs are for Windows users. But if you'd like a list of some websites I've found with links to Mac software (or if you've found some yourself), please email me through my StarLore site at www.starlore.net.

You can download two main kinds of software. Freeware, as the name implies, is completely gratis and comes without any usage restrictions. Shareware, on the other hand, requires a small payment to use it to full effect. You can download it for free, but until you pay, certain features might be disabled, the program might stop running after 30 days, or a "nag box" might appear from time to time.

Let's look at some almanac software first. *Planet's Visibility* from Alcyone Software is freeware for Windows 95, 98, or Me. This program shows when the sun, moon, and planets are visible throughout the year and computes each object's altitude, azimuth, and magnitude. It also depicts both lunar and solar eclipses, the four Galilean satellites, and a basic representation of the planets. The moon's phases are calculated, but not shown. Download the program as a 4.6Mb, self-installing file from http://www.alcyone.de/PVis/english/ProgramPVis.htm.



☑ use DST ☐ sunrise/sunset ☐ grid ☑ eclipses

latitude	longitude	timez (DST)
52° 31' N	13° 19' E	60 (+60)

date	time	altitude	azimut	mag
21/4/2001	09:40	38.1°	231.5°	4.1

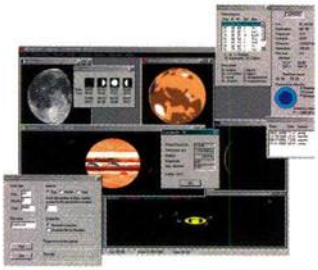
Berlin (Germany)

year 2001 object Venus

The program has the following functions:

- it calculates (in intervals of 4 minutes for one year)
  - the positions of the planets, the sun and the moon (horizontal coordinates)
  - the magnitudes of the planets
  - the moon-phases
- it shows the values of these parameters in dependence of the position of the mouse cursor ①
- it reads the location of observer from an enlargeable database (Paradox-table) with more than 400 entries ②
- it marks the actual local time in the plot ③
- it lets the user change the year of observation from 2000 BC to 4000 AD ④
- it marks the times of visibility of the objects in a special color ⑤
- it modulates the brightness of this color in dependence of the apparent magnitude of the planet (if the color resolution of your graphics adapter is greater than 16 bpp)
- it shows the times of twilight (if the current object is the sun)
- it considers Daylight Savings Time
- it has customizable color assignments ⑥
- it shows the times of solar and lunar eclipses (if the current object is the sun or moon) and local circumstances of the eclipses (accurate for historical eclipses eg. the "historical" total solar eclipse of 899 BC) in separate windows ⑦
- shows the positions of the Galilean moons of Jupiter ⑧
- it shows the rotational and illumination parameters of all the planets ⑨
- it can interpret command line parameters

Planet's Visibility **shows when the sun, moon, and planets are in sight throughout the year.**



Meridian **is an excellent resource for planet-watchers.**

A similar, but more basic freeware program is *Dark Skies* by Todd Daniels. This produces a simple chart for your location showing day, night, and twilight hours over the course of the year as well as the occurrences of both full and new moons. By clicking on the chart, you can see sunrise and sunset times and the night length for a certain date. It even notifies you when moonlight will affect observing. *Dark Skies* can be downloaded as an 82kb-zipped file from http://pages.sprint.ca/todd/dark_skies.html.

You might also like to try *Meridian* by Claude Duplessis. It's available as freeware in English, French, and Spanish as a 1.6Mb file for Windows 95, 98, or NT from http://pages.infinit.net/merid/index.html.

Meridian has neither graphs nor powerful ephemerides tools. Its strength lies in its planetary information: You can glimpse current views of the major planets and check their coordinates, distances, phases, and magnitudes. A graphic compares each planet's current angular size with its maximum and minimum. Other events include upcoming planetary conjunctions and the seasons on Mars.

If you are looking for more detailed information, don't miss the *Ephemeris Tool* from Astronomiesoftware Dings. This user-friendly shareware generates an exportable spreadsheet similar to Excel's. Just by clicking on any of the toolbar icons, you can generate ephemerides for objects in our solar system (including comets and asteroids) as well as variable stars over any given period. Events for Galilean and saturnian satellites can be predicted, as can transits, occultations, and eclipses. All of the databases can be added to or amended. The shareware can be downloaded as a 2.9Mb-zipped file for Windows 9X, 2000 or XP from http://virtualskysoft.de/asappsen.htm.

WinEphem by Mark James is a small freeware program for Windows available as an 84kb-zipped file from http://www.geocities.com/tmarkjames/WinEphem.html. By specifying your location, a date, and a time (or using your system clock), the program will calculate the ephemerides for the sun, moon, and planets. Two drop-down menus at the bottom of the screen allow you to find the location of either a star or a deep-sky object, and the program computes rising, transit, and setting times. — *Richard Bartlett has been infatuated with the sky since he was six. He lives in Luton, England.*

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Case #773 (60/70)	64
Case #774 (90)	100
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Dew shield 60/70	20
Dew shield 90	25
Dew shield 105	28
Dew shield 125	30
Filter set #3200	40
Finder #825	52
Finder #827	52
Focuser #1244	124
Focuser #1247	124
Prism 45° #932	50
Prism 45° #933	50
Tripod #880	32
Tripod #881	62
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11" full aperture	179
12" full aperture	189

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12" flexible	74
12" **metal**	179

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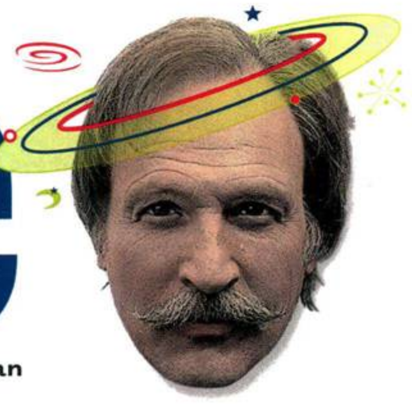

by Bob Berman

The Man Who Fell to Earth

Gravity may seem like a drab textbook topic. But this simple reality turns out to be one of the most bizarre and tormenting aspects of the entire universe.

We take for granted the magic of things being pulled toward other things. Yet can anyone really explain gravity, or claim to know what's actually going on? The fact is, nobody can. Einstein couldn't, and neither can Stephen Hawking or any other science luminary today.

Let's watch what happens when we fall. Any kid who has jumped from a fence knows that the higher the leap, the more it hurts. That's because we then hit the ground at a faster speed. Maybe you still recall the famous number "32 feet per second per second" — the acceleration experienced by a falling body. I'll never understand why schools insist on expressing speed that way (or as 9.8 meters squared) when it's easiest to grasp in everyday language: 22 miles per hour.

Falling for a single second causes you to slam into the ground at 22 miles per hour. Each additional second you're airborne makes you hit the ground another 22 miles an hour faster. Simple.

To be airborne for exactly one second, you'd have to jump from a height of 16 feet. One and a half stories. Painful, but not generally fatal.

Two seconds of falling, achieved by jumping off a five-story building, accelerates you to 44 miles an hour, an impact usually not survivable. If you want to know how fast a penny would fall if tossed from the Golden Gate Bridge, or what speed a bungee jumper attains when leaping from a 200-foot perch, it's easy to calculate. Just multiply the height (in feet) by 64.4 and then find the square root of this number. That's the final velocity in feet per second. To get miles per hour, multiply this by 0.68.

The greatest speed you'd reach if you jumped from the highest possible perch (that is, if you fell toward Earth from infinitely far away, beyond the moon even) and if air resistance didn't slow you down, would be 25,000 miles per hour. That's exactly the same speed needed to escape from Earth with a single upward blast, like being fired from a cannon. So the velocity you need to escape from any celestial body is the same as the speed with which you'd crash into it if you fell there from a great height. For the moon that ultimate motion is 5,368 miles per hour. For the sun it's more than a million mph, or 384 miles per second. That's how fast an incompetent, out-of-fuel alien spacecraft captured by the sun's gravity would be sucked into its surface. Ouch.

Here on Earth, air resistance quickly slows things down. In skydiving class they teach that if you spread your arms and legs and let your body present maximum surface to the wind, you won't fall faster than 120 miles per hour. That's called "terminal velocity" and it's reached after jumping from a height of just 500 feet, or 50 stories. Unless you assume a streamlined diving position, in which case you can bring yourself to nearly 200 miles per hour, you'll not accelerate further by jumping from anything higher than the 50th floor. Those daredevils who leap from lofty rooftops choose very high buildings just to buy themselves enough air time for their parachutes to open — an excellent idea.

But why should Earth attract your body? And also, why shouldn't you be pulled more quickly than a lighter object? The answer is: you actually are. Despite the famous supposed Galileo demonstration from the leaning tower of Pisa, in which dropped objects of two different weights hit the ground together, and the commonly repeated claim that everything is pulled equally by gravity, heavier objects *are* yanked more forcefully than lighter ones.

If you jump off a table just as a fork falls off, Earth's gravity pulls on your body with greater power than it tugs on the fork. But since you weigh so much more (especially after Thanksgiving) your mass takes longer to speed up, just as a truck accelerates much more sluggishly than a sports car. The result is actually a wash: your body's yanked with more force but accelerates more reluctantly — and you end up falling at the same rate as the fork.

Fine. But we still haven't explained *why* all of this happens. Newton's notion of a mysterious unseen force is no longer accepted. But Einstein's idea of gravity being an aspect of the warping of space-time doesn't fully explain it either. Kids at school are still taught the older Newtonian way, that Earth circles the sun because of the sun's gravitational "pull." Few science curricula provide children with the superior Einstein concept, that Earth merely follows a straight path through curved space-time. And, because the sun has warped the space here in its vicinity, our planet merely plummets along the shortest, straightest, laziest route (called a geodesic) in this curved matrix, which results in carrying us back to our starting point after a year.

Visualizing gravity as a consequence of a region's three dimensional geometry (four dimensions when you include time) allows us to calculate motion with wonderful accuracy. In sum, heavy items like the sun measurably warp the local space-time, and this curved space then dictates how everything in its vicinity (including the sun itself) has to behave. It's a crisp symbiotic relationship. (But it isn't for the faint-hearted. General Relativity's field equations are so laborious that even NASA avoids them when calculating spacecraft trajectories, in favor of the far simpler Newtonian math.)

Nonetheless, our ability to compute how it behaves still doesn't tell us what gravity truly is. As one of the universe's four forces, gravity is by far the least understood. The other three (electromagnetism and the two forces, weak and strong, that operate only within the tiny regions in and around atoms) have even been theoretically tied together, especially the weak force with the electromagnetic. But gravity has managed to elude any and all attempts to weave it into any larger picture, to connect it with the others, and unify it with the cosmos as a whole.

Is its power dependent on the structure of the rest of the universe? Would the value of the gravitational constant change over time as clusters of galaxies move further apart, as some physicists suspect? Will Earth's gravity grow weaker as the universe expands?

Can gravity be the influence from some other dimension that partially spills over into ours? Is it spread by theorized particles called gravitons, that have yet to be verified? Does a dropped object seem to move toward the floor because it's actually motionless while the room itself accelerates through space-time the other way?

We still don't know. And autumn's falling apples, Newton's original inspiration for tackling gravity's mysteries, still plop plop plop all around us. ■

Bob Berman regularly writes Astronomy's *"Strange Universe" column. He is also the author of entertaining and inspiring guides to the night sky, including* Secrets of the Night Sky *(HarperPerennial, 1996).*

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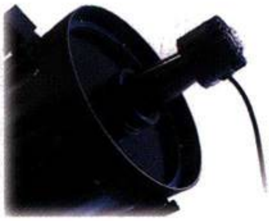

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Jerry Schad

Attendees at mid-November star parties might be fortunate enough to view a Leonid fireball.

Astronomers have their own celebration in Norway on **November 10** with **Astrofestival 2002.** This yearly public event, held at the University of Oslo at Blindern, covers topics ranging from cosmology to space travel. Featured this year are guided tours through a scaled-down solar system, an astrobazaar, contests, lectures, and many other enjoyable activities.

For more information, contact the Univeristy of Oslo at Blindern at (47) 22 85 50 50; e-mail astrofestival@fys.uio.noor; Astrofestival 2002 website at www.astrofestival.no/.

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Under One Sky

Adler Planetarium and Astronomy Museum, Chicago. A year-long program celebrating the influence of astronomy in cultures around the world, spanning thousands of years. Under One Sky features the sky show *Skywatchers of Africa* and gallery show *Bringing the Heavens to Earth*. For more information, contact (312) 922–STAR; website, www.adlerplanetarium.org.

PERMANENT EXHIBITION

Explore the Universe

The Smithsonian Institution's National Air and Space Museum in Washington, D.C., is presenting a new, permanent exhibition covering the evolution of man's tools for searching the heavens – from the naked eye, to telescopes, photography, spectroscopy, and present-day use of digital media. Admission is free. For more information, visit its website, www.nasm.si.edu/galleries/gal111/.

OCTOBER 25–26

International Dark Sky's Fall Meeting

Boston Museum of Science, Boston and Harvard College Observatory, Cambridge, Massachusetts. For more information, visit the NELPAG/IDA website, cfa-www.harvard.edu/cfa/ps/nelpag/meetings.html.

OCTOBER 30–NOVEMBER 3

Deep South Regional Stargaze

Percy Quin State Park, McComb, Mississippi. The featured speaker will be David Levy. For more information, contact Barry Simon, (504) 283–7592; e-mail, bsimon615@aol.com; website, www.nightskydesign.com/pas/.

NOVEMBER 2

Dark Sky Star Party

Saddleback Butte State Park, Lake Los Angeles, California. Sponsored by the Antelope Valley Astronomy Club, observers are welcome to stay at the reserved camping area. For more information, visit the AVAC website, www.avac.av.org/.

NOVEMBER 2

Jersey Astronomical Conference and Showcase

Union County College, Union, New Jersey. JACS, hosted by the Amateur Astronomers Inc., will feature exhibitors, prizes, lectures, workshops, and seminars. For more information, call (908) 233–8741; e-mail, jacs@asterism.org; website, www.asterism.org/.

NOVEMBER 2

North Texas Skywatch

Lake Mineral Wells State Park, Mineral Wells, Texas. This star party is hosted by Lake Mineral Wells State Park, Tarleton State University, and Tarrant County College. For more information, visit its website, www.tarleton.edu/~planetarium.

NOVEMBER 3–10

Chiefland Star Party

Chiefland Astronomical Village, Chiefland, Florida. Chiefland Star Party will have vendors, guest speakers, an astrophotography contest, and contests. For more information, visit its website, www.c-av.com/.

NOVEMBER 3–8

Galactic Center Workshop

Ohana Keauhou Beach Resort, Kailua-Kona, Hawaii. The meeting will feature astronomical lectures and a variety of tropical activities. For more information, contact Angela Cotera, cotera@as.arizona.edu; Tom Geballe, tgeballe@gemini.edu; website, www.gemini.edu/science/gc_conf/.

NOVEMBER 9

LVAAS Star Party

South Mountain, near Allentown, Pennsylvania. Join the Lehigh Valley Amateur Astronomical Society for a public star party at the LVAAS's three observatories on top South Mountain. For more information, contact David Raker, draker@cedarcrest.edu; website, www.lvaas.org/.

NOVEMBER 9

NOVA Star Party

Horseshoe Lake, near Chico, California. NOVA invites the general public to a night of stargazing. For more information, visit its website, http://rigel.csuchico.edu/nova/calendar.html.

NOVEMBER 14

Winter Wonders

State Museum of Pennsylvania, Harrisburg. This seasonal star show showcases the Star of Bethlehem, Christmas traditions, and international winter solstice celebrations. For more information, visit the museum's website, www.statemuseumpa.org/exhibits/planetarium.html.

NOVEMBER 15

Encontro Nacional de Astronomia

Ouro Preto, Brazil. Registration deadline is November 10. For more information, contact Gilson Nunes, seaop@em.ufop.br; website, www.geocities.com/naelton.

NOVEMBER 18

Canary Islands Winter School of Astrophysics

Puerto de la Cruz, Tenerife, Canary Islands, Spain. The theme for the 16th annual island gathering is "Dark Matter and Dark Energy in the Universe." Organized by Instituto de Astrofisica de Canarias, this year's meeting features eight prestigious speakers who research dark matter. For more information, contact Lourdes González at xivwinter@ll.iac.es; website, www.iac.es/winschool-2002/1announce.html.

NOVEMBER 18

Skywatch

Dreyfuss Planetarium, Newark Museum, Newark, New Jersey. For more information, visit the Museum's website, www.newarkmuseum.org/.

DECEMBER 7–8

ASV Star-B-Q

Leon Mow Dark Sky Site, Heathcote, Victoria, Australia. The 12th annual Star-B-Q is hosted by the Astronomical Society of Victoria. For more information, visit its website, www.asv.org.au/.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

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Alaskan aurora photograph by Mike O'Leary

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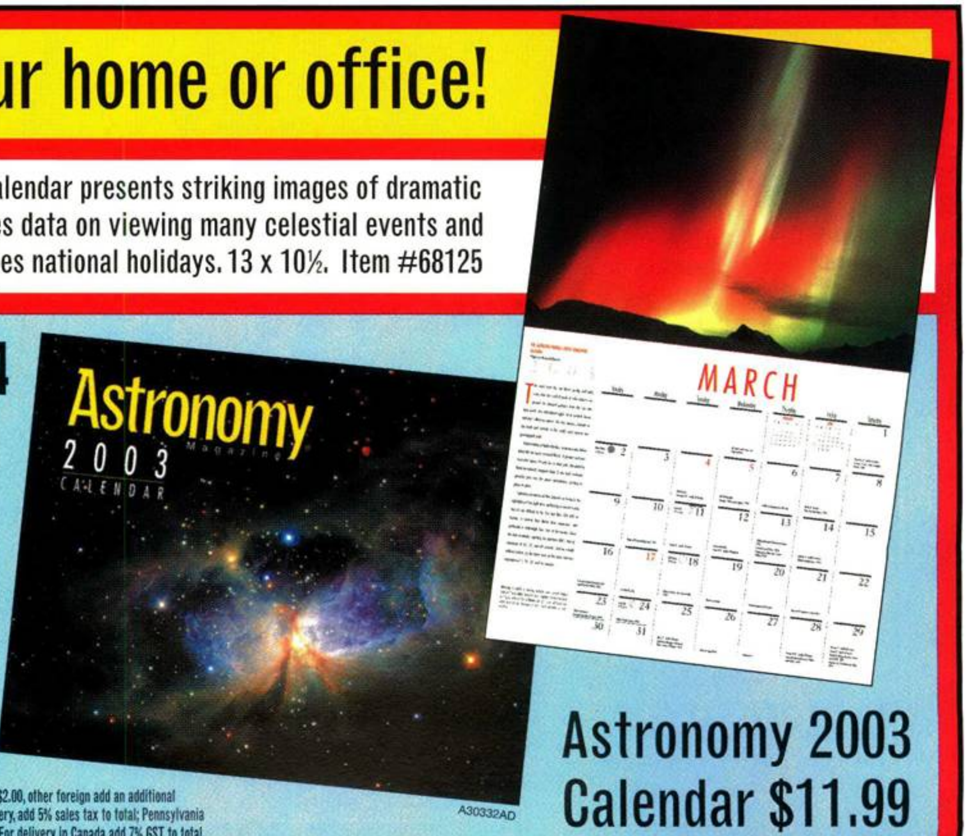

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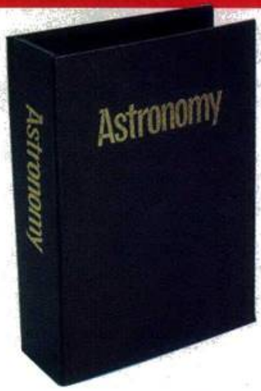

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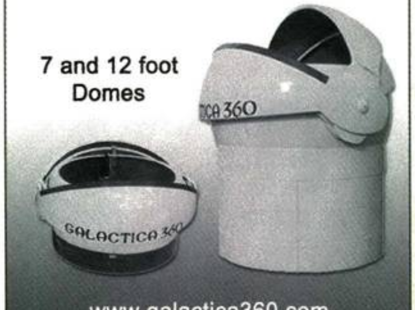

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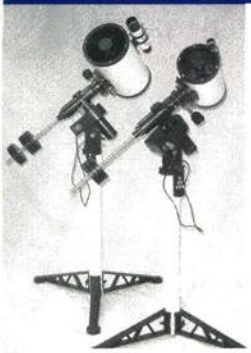

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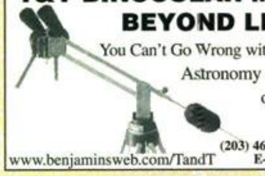

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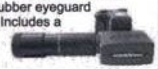

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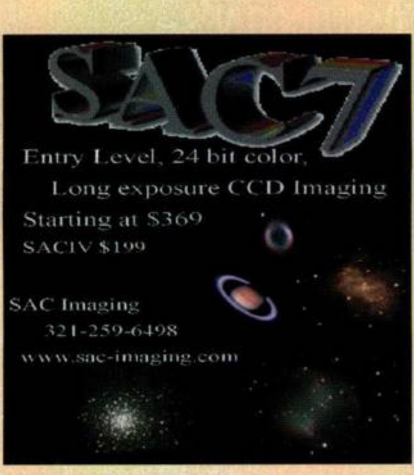

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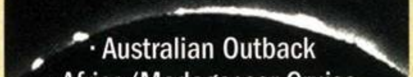

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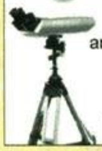

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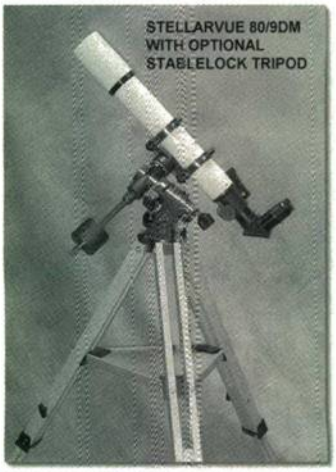

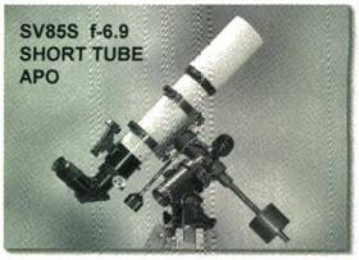

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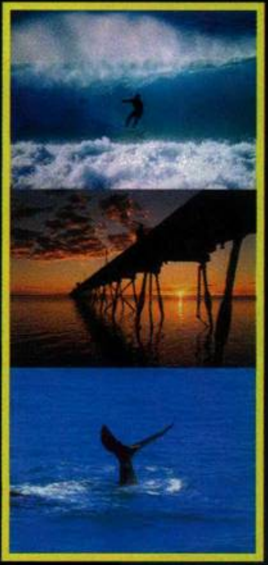

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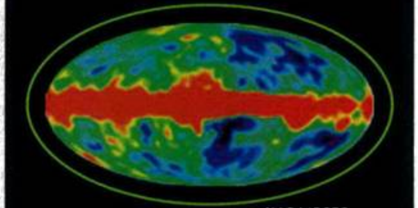

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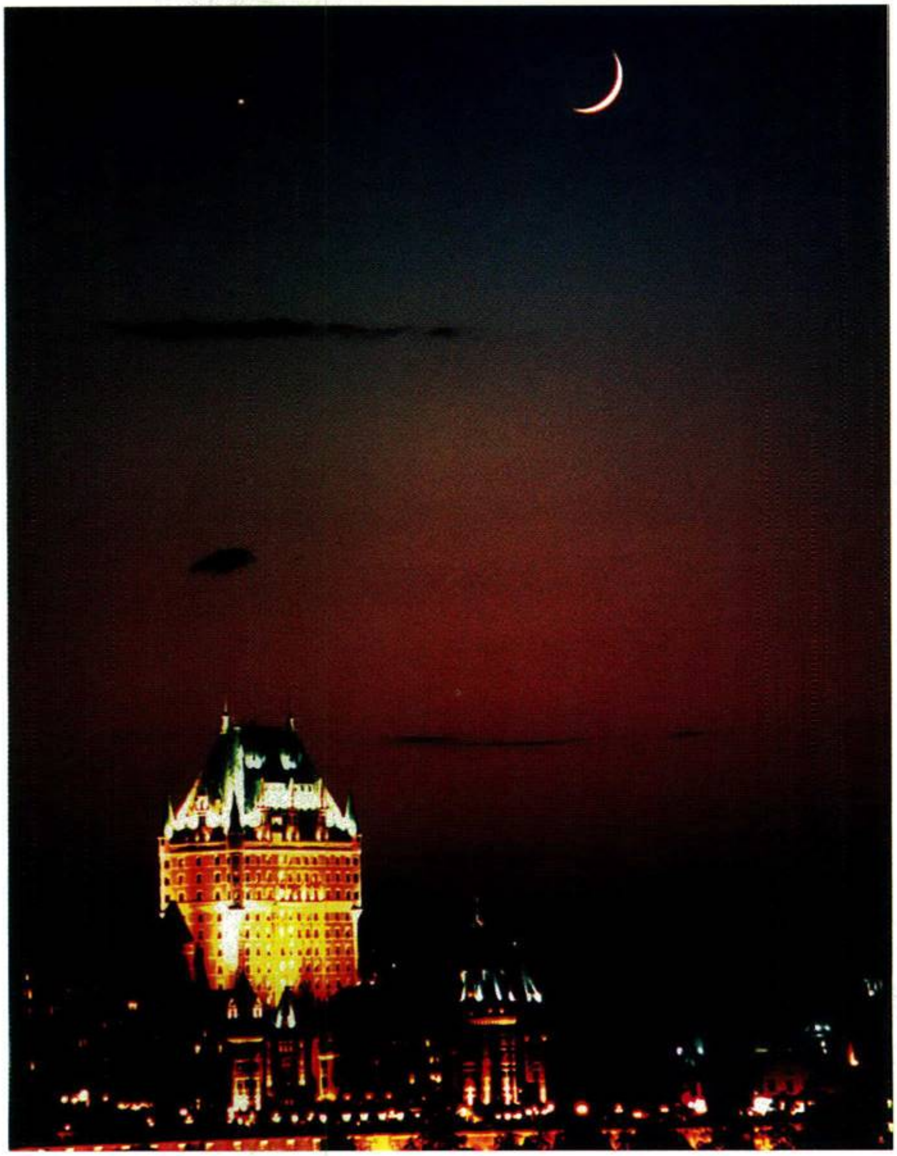


▲ The Moon and Jupiter over Le Chateau Frontenac

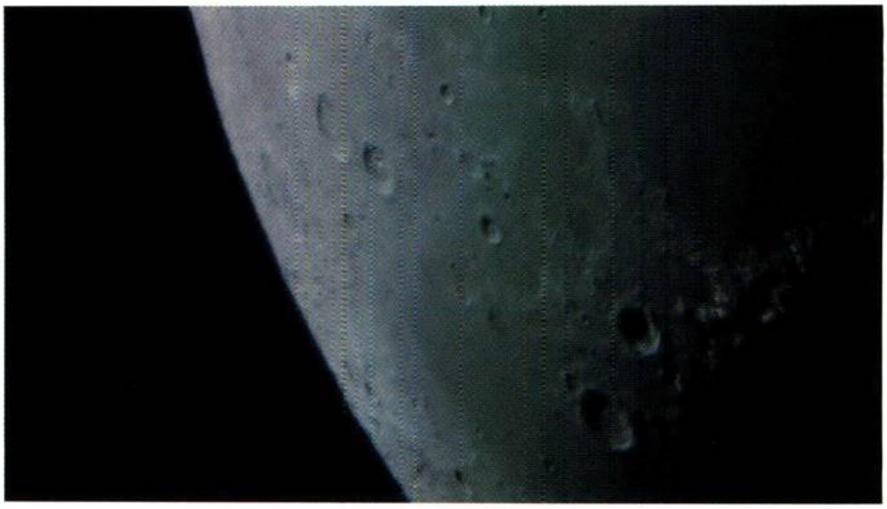
DOMINIC CANTIN

(80mm lens at f/4.5, one-second exposure taken June 13 in Quebec City)

▶ Lunar Closeup

MEHMET GUNSUR

(8-inch SCT, 13mm eyepiece, Coolpix 950 CCD camera)



▲**Irregular galaxy NGC 4631 and NGC 4627 in Canes Venatici**

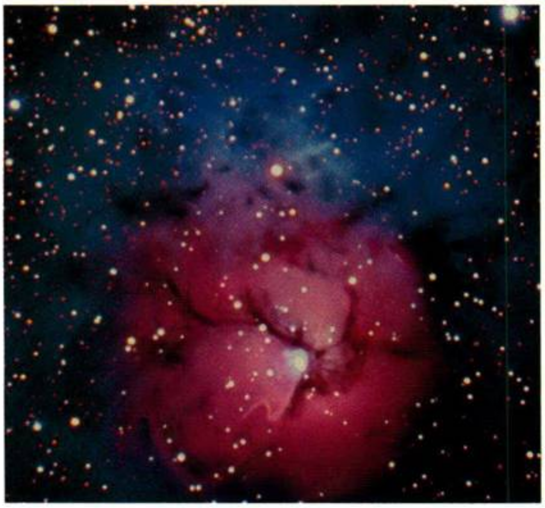
RALPH SARGENT

(12-inch SCT at f/6.3, SBIG ST-7E CCD camera, composite exposure)

◀**NGC 6543**

AL KELLY

(32-inch reflector, SX MX916 CCD camera, taken August 2)



▲ The Trifid Nebula (M20)

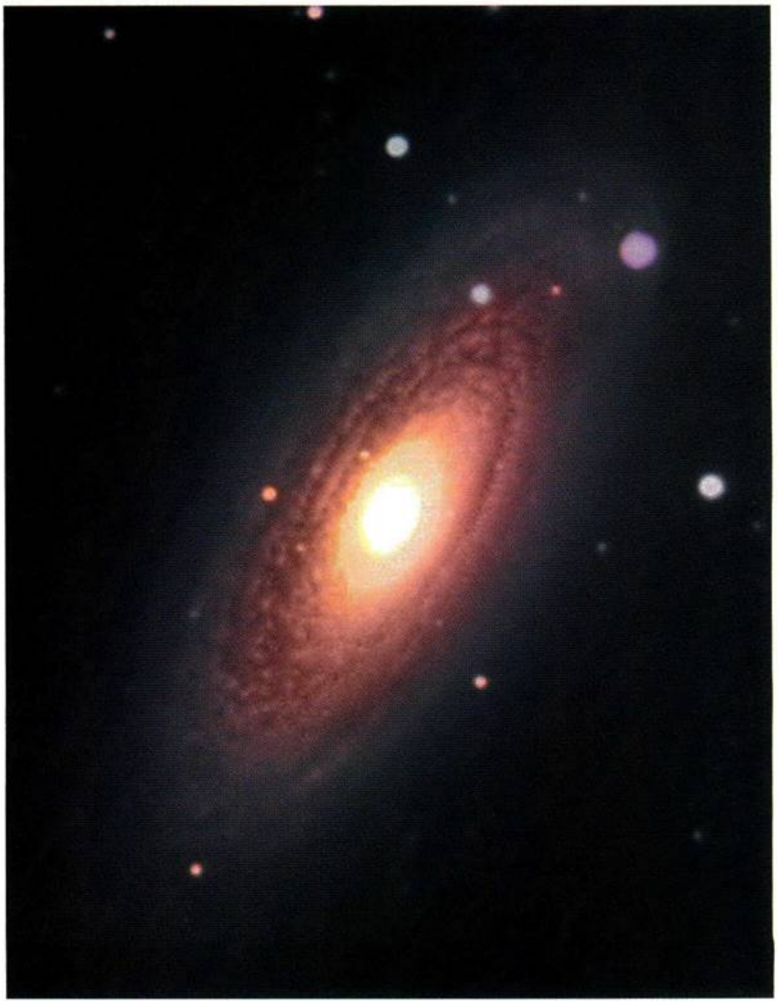
GEORGE GREANEY

(14-inch SCT at f/7, hypered Kodak PPF 400 film, composite of three 40-minute exposures)

▶ Spiral Galaxy NGC 2841 in Ursa Major

RALPH SARGENT

(12-inch SCT at f/6.3, SBIG ST-7E CCD camera, composite exposure)



◀ Emission Nebula NGC 6820 and Open Cluster NGC 6823 in Vulpecula

ROBERT GENDLER

(12.5-inch Ritchey-Chrétien scope at f/6, ST-10 CCD camera, composite exposure)

▶ The Pinwheel Galaxy (M33)

MATT RUSSELL

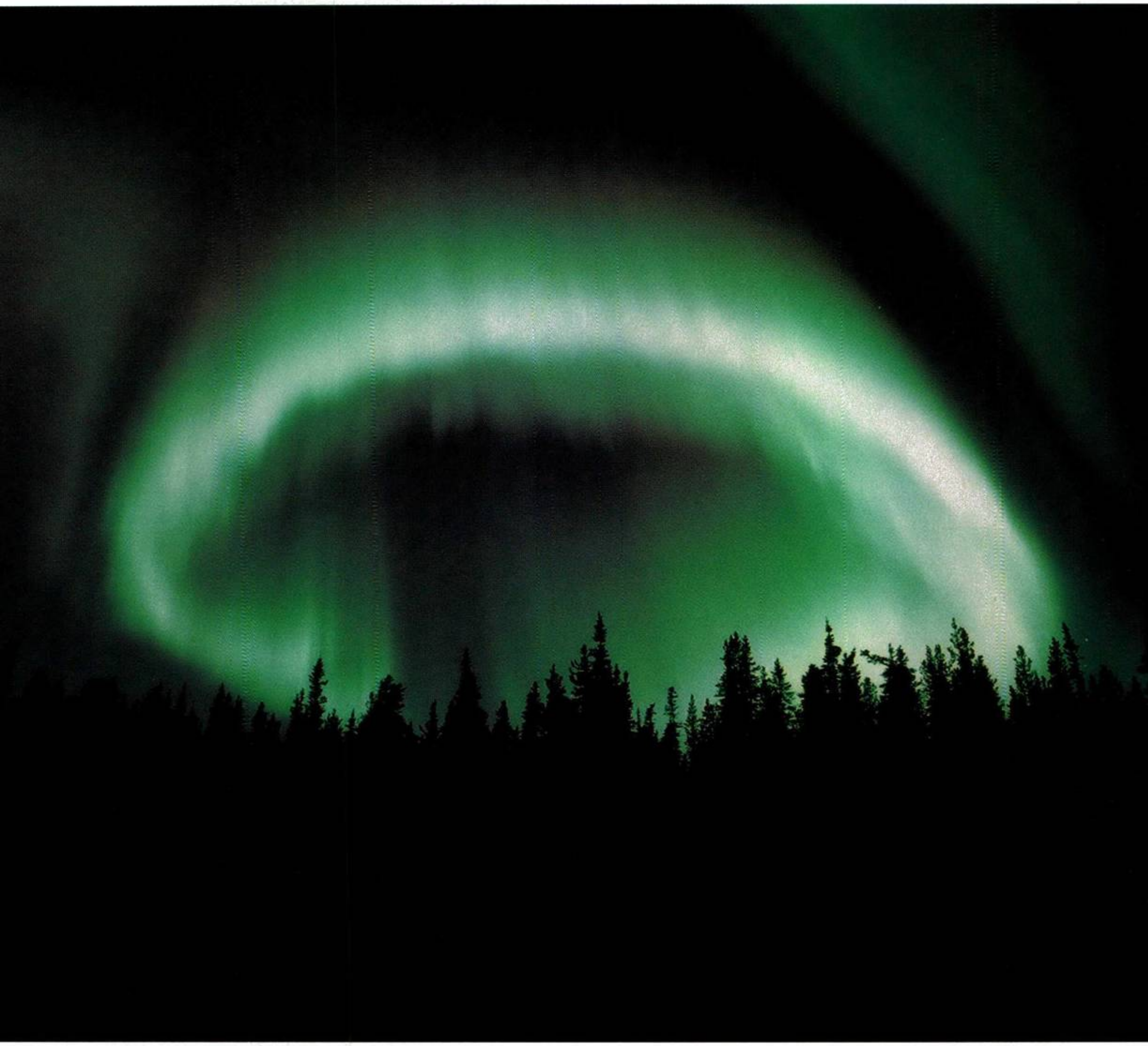
(4-inch apochromatic refractor at f/8, SBIG ST-10E CCD camera, composite exposure taken July 13)

▼ Scorpius Rising

JERRY SCHAD

(24mm lens at f/1.7, Ektachrome P1600 film, 30-second exposure taken over the Sonoran Desert Museum, Tucson, Arizona)

This month's best astrophoto



▲ Canadian Aurora

MICHAEL KLENSCH

(24mm lens at f/2.8, Fuji 400 ISO Superia film, 15-second exposure)

Michael Klensch captured this unusual auroral display in British Columbia on October 3, 2001.

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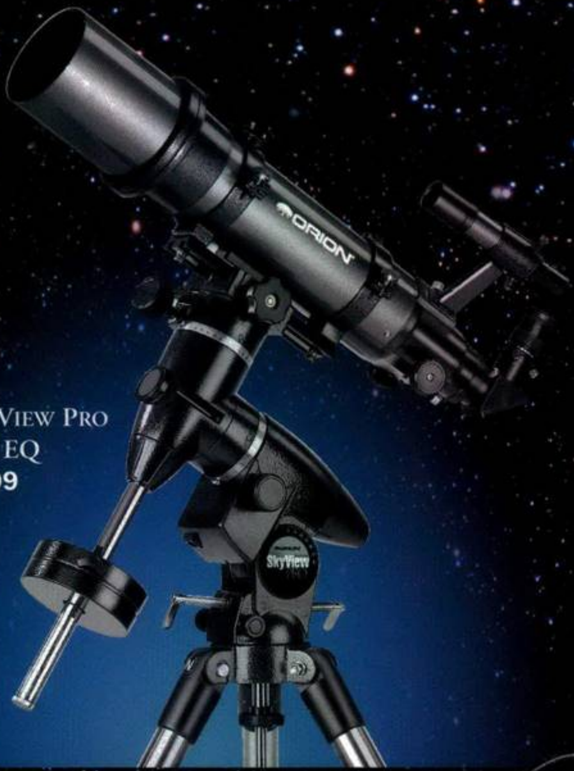

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